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DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION  
WEAPONS SYSTEMS RESEARCH LABORATORY

TECHNICAL REPORT

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TECHNIQUES FOR MEASUREMENT OF WORK INPUT DURING GUN PROPELLANT PROCESSING

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S U M M A R Y

This report deals with the principles, application and performance of load and work sensing techniques used on propellant mixers and rolling mills. The current and recommended alternative methods used in load sensing during manufacture of propellants are outlined.



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## 1. INTRODUCTION

In processing gun propellant it is important to measure the viscous load at the mixer blades, and the work input by the roll mill to achieve quality and reproducibility of propellant material.

This report outlines the instrumentation developed for measurements of work input on the sigma bladed mixers and roll mill situated at the Processing Development Area, Propulsion and Ballistics Division of Weapons Systems Research Laboratory.

Gun propellants can be sub-divided into single base, double base, triple base, lova and nitramine propellants. The processing of these propellants for use in gun ammunition is carried out in seven major unit operations, namely de-hydration, incorporation, maceration, blocking, extrusion, granulation and finishing.

The incorporation stage of gun propellant processing includes mixing and dispersion of the propellant ingredients and with single base propellant a macerator is used, subsequent to the incorporation stage to impart more work into the mix. The load sensing technique used on this unit is similar to that used for the incorporator.

A roll mill is utilised in the processing of triple base propellants. The triple base propellant material is "nipped" by two rolls, moving in opposite directions, into a rubbery sheet. This process is used between the incorporation and extrusion stages.

## 2. THE DESCRIPTION OF INCORPORATORS AND ROLL MILL

### 2.1 1 kg incorporator

The 1 kg incorporator is patterned on a Baker-Perkins unit. The sigma blades in the mixer are driven by a 1.1 kW (1425 rev/min max) flame proofed motor via a 2:1 reduction gear box, a 40:1 worm reduction gear circuit, and a CF type variable speed drive (see figure 1). The two Sigma blades are counter rotating with one blade operating at twice the speed of the other (see figure 2). The mixer is jacketed for heating and cooling purposes and temperature of inlet, outlet water and colloid are monitored during the mixing process.

### 2.2 5 kg incorporator

The 5 kg incorporator is a proprietary Baker-Perkins unit on which the 1 kg incorporator was based. It is driven by a 3.7 kW (1440 rev/min max) motor. The variable speed drive on this incorporator is a Renold Croft CA type. The reduction gear unit has a 10.8 to 1.0 ratio (see figure 3). The mixer is jacketed for heating and cooling purposes. The temperatures monitored are as for the 1 kg mixer.

### 2.3 Roll mill

The roll mill could be compared with a wringer on an old fashioned washing machine (see figure 4) where the propellant material is fed through two horizontal, parallel cylindrical rolls which are water heated by a Churchill Chiller and rotate at dissimilar circumferential speeds. The gap between the rollers is set at 2.0 mm and when triple base propellant material is fed to the rolls, it adheres to the slower of the two rolls. The other roll subjects the propellant to a shearing and squeezing action which works the material into a rubbery sheet. The propellant material is

folded over so that three sheet thicknesses enter the rolls at each pass and the number of passes determines the work performed on the propellant.

### 3. CURRENT LOAD SENSING METHODS

#### 3.1 Load sensing on incorporators

The reactive force developed on the incorporator by the action of the mixer blades on the colloid is measured by interface strain gauge load cells (see figure 5) and output is displayed by a Bristol Babcock microprocessor system. The interface load cell is a transducer which consists of a strain gauge fitted or bonded to a stress member. The mixer bowl pivots about the blade axis and a force is applied to the load cell by the turning moment from the bowl. This load alters the electrical resistance of the strain gauge as:

$$R = \frac{Pl}{a} \quad (1)$$

where R = resistance  
P = resistivity  
l = length  
a = area

The torque can be calculated by:

$$T = Fr \quad (2)$$

where T = torque  
F = force  
r = radius

and

$$F \propto R \quad (3)$$

The above mentioned radius is the distance between the measurement point and the pivot point. For example, for 1 kg and 5 kg incorporators, the distances are 165 mm and 284 mm respectively.

The power is calculated by:

$$P = T\omega \quad (4)$$

where P = power  
T = torque  
 $\omega$  = angular velocity

Hence work input is calculated from:

$$W = \int_0^t P dt$$

where W = work  
P = power  
dt = time increment  
t = time

Appendix I details work calculations for load cell torque measurements.

### 3.2 Load sensor on the rolling mill

A microprocessor based power meter (see Appendix II and figure 6) monitors the power surges during roll mill operations. A University Graham AWT-330 power transducer is utilised to continuously monitor the electrical power drawn by the roll mill motor. The power transducer is connected as a 3 phase 3 wire unbalanced-load watt meter, which senses the three phase voltages and 2 line currents via a 60:5 current transformer. The electrical terminations, fuses, and current transformers are located in the motor starting box.

The microprocessor unit gives a program run summary printout consisting of:

- (a) Total number of passes
- (b) Total energy on all passes
- (c) The pass with maximum energy
- (d) The pass with maximum peak power.

A typical pass detection diagram is shown in figure 7.

## 4. PERFORMANCE OF LOAD SENSING DEVICES

### 4.1 Incorporator load sensor performance test

#### 4.1.1 Interface load cell measurements

Performance of the load cell on the 1 kg and 5 kg incorporators was assessed during the mixing of gun propellants.

The following experiments were performed on the 1 and 5 kg mixers.

- (a) 1 kg mixer, explosives mixing, with torque readings from the load cell recorded every 5 min.
- (b) 1 kg mixer, with the mixer stationary and empty, and the torque readings recorded every 2 min. The temperature of the mixer bowl was increased over a period.
- (c) 1 kg and 5 kg mixers, with the mixers empty, and torque readings recorded every 2 min. The temperatures of the bowls were increased

by 5°C at a time and allowed to stabilise. Each mixer was switched on with forward or reverse actions prior to the torque readings being taken, and outlet water temperature recorded.

(d) 1 kg mixer and 5 kg mixers, with the mixers empty and running continuously, and torque readings were recorded every 2 min. The temperatures of the bowls were increased in 5°C steps over a time period.

#### 4.1.2 Motor power measurements

The load cell measurements were compared with electrical power measurements and the incorporator's motor load was monitored by a Hioki Power Hi Tester (see Appendix III). A chart recorder connected to the power meter recorded all the motor load measurements at a constant mixer blade speed of 23 rev/min on both incorporators during these trials.

#### 4.1.3 Pressure transducer measurements

Oil taps and connectors were fitted to the ports on the CF12 variable speed drive on the 1 kg mixer to allow connection of a pressure transducer (a 5000 psi (34.475 MPa) Schaevitz pressure transducer) to monitor the hydraulic pressure throughout the mixing cycle. (See figure 8). The pressure transducer was connected to an amplifier and readout unit (see figure 9(a) and (b)). The transducer and amplifier readout unit were enclosed in a flame proofed box with the output of the amplifier connected to a remotely located Honeywell electronic 193 chart recorder.

As the mixer load increases, more work has to be transmitted through the hydraulic power unit to prevent speed reduction. This results in an increase in hydraulic pressure. The pressure readings and motor measurements were recorded simultaneously during trials and plotted on the same chart recorder. The power measurements were monitored by an Honeywell electronic chart recorder.

#### 4.2 Roll mill load sensing measurements

The roll mill power analyser measured the power consumption of the roll mill motor during propellant rolling operations. Initially the power analyser measured the power of the roll mill motor without any propellant in the rolls. Rolling passes were then made by feeding the propellant material through the rolls, and after each pass the microprocessor unit printed the pass number, pass energy, accumulated energy and peak power (nett). The accuracy of the power transducer is specified as  $\pm 0.5\%$ .

### 5. DISCUSSIONS

#### 5.1 The interface load cell measurements

The trials carried out in the 1 kg mixer with the load cell indicated a temperature dependence (see figure 10). When the temperature of the 1 kg mixer was maintained at ambient (25°C) and mixing initiated, the torque values displayed a constant level of 90 (N-m). As the temperature of 1 kg mixer was increased to 60°C (refer figure 10), the torque level increased to 100 N-m and tended to fluctuate between 75 and 100 (N-m).

Figures 11(a) and (b) display the torque readings with time, where the results were monitored with mixers under idle conditions. The results show the load cell readings increasing with temperature. During the trials the

ambient temperatures varied between 23°C to 25°C and the torque readings followed the trend of mixer outlet water temperature measurements. Hence a linear relationship between outlet water temperature and load cell reading can be established.

Figures 12 and 13 display the results obtained with the empty mixers (1 kg and 5 kg capacities) started and stopped in a cycle. The mixer temperature was increased from ambient 20°C to 40°C. The results still show the trend of the load cell measurements increasing with outlet water temperatures.

Figures 14 and 15 display the load cell measurements during continuous mixer operation, with the mixers empty. The results still show the phenomena observed in figures 11(a), 11(b), 12, 13, 14 and 15.

The manufacturers of the load cell were contacted to obtain information on the interface load cell. They informed us that when temperature is applied to a load cell it has a creep rate less than 0.03% (full scale) within twenty minutes, and a hysteresis of 0.02% (full scale). This suggests that the load cell mechanics are insensitive to temperature rises in the mixer bowl. The effect of temperature increase on the load cell on a static mixer could be explained as thermal expansion of the bowl causing the T piece (figure 5) on the mixer to move and impart an additional force to the load cell.

In the reverse mode of mixing, the mixer bowl was observed to be frequently lifting off the load cell. The effect was only observed during high torque periods, and as a result the load cell displayed false readings. The errors caused by the temperature effect on the load cell could also be eliminated by locating the load cell away from the mixer bowl by a pivot arrangement. However, in the long term an alternative technique of load sensing should be investigated to produce accurate measurements.

## 5.2 The interface load cell versus electrical motor load measurements

Figure 16 displays power versus time plots for load cell and motor power on the 5 kg incorporator trials. The high torque value observed in figure 16 is due to bindup of propellant material during mixing. The bowl temperature was maintained at 50°C. The motor power measurements tended to follow the load cell measurements before bindup, but tended to fluctuate after bindup. Another observation is that load cell values were high in value-comparative to motor power measurements before bindup and maintained lower values after bindup. At bindup, load cell measurements only reached power value of 980 N-m in place of power meter measurement of 1300 N-m. These discrepancies between load cell measurements and power meter measurements are not fully understood. But suggestions are that discrepancies created could be due to temperature effects on the load cell.

## 5.3 Mixer drive hydraulic pressure versus electrical motor load measurements

The pressure measurements were plotted against motor load measurements for a complete mix cycle on the 1 kg mixer. (See figures 17(a), (b) and (c)). The apparent time delay between pressure and power results on the plots are due to an offset of the pen on the chart recorder.

The manufacturer's specifications indicate that the CF12 hydrostatic variable speed drive at a maximum speed (1420 rev/min) has a power output of 0.93 kW and produces hydraulic pressure of 4.53 MPa. The specification also indicates that output power varies linearly with input power to the motor.



The minimum values of pressure and input power of the CF12 variable speed motor system were measured with the mixer running at no load conditions and were found to be 1.38 MPa and 0.25 kW respectively. Hence by substituting the maximum values from specification and minimum measured values a theoretical relationship can be derived.

For the relationship between the input power and the hydraulic pressure:

$$P = mP_s + C \quad (6)$$

$P$  = Input power (kW)

$P_s$  = Pressure (MPa)

$m$  = Slope

$C$  = Intercept

where

$$P = 0.269 P_s - 0.121 \quad (7)$$

The relationship between the output power and the hydraulic pressure would be a line with the same slope, but a lower intercept with y axis.

Equation (7) was checked with measured test values on figures 17(a), (b) and (c). A modified relationship was derived which is displayed with equation (7) in figure 18. The new modified relationship becomes:

$$P = 0.0078 P_s + 0.125 \quad (8)$$

Equation (8) is more accurate than equation (7) as it was derived from measurements obtained in various stages of mixing process, but further testing with some experimental modifications would provide better accuracy and repeatability of measurements.

Suggested experimental modifications:

(a) A 34.46 MPa maximum pressure rated transducer was utilised for the test, but from the variable speed drive specifications, the maximum obtainable pressure from the hydraulic pressure drive system is 4.53 MPa. A 6.89 MPa transducer is to be utilised for pressure in future trials to obtain improved accuracy in this measurement.

(b) No results were obtainable during reverse mixing. Another pressure transducer should be utilised to measure hydraulic pressure when the mixer is in a reverse mode of operation.

#### 5.4 In-line torque transducers on mixer drive shafts

In-line torque transducers on the incorporator shafts could be another approach to measure torque on gun propellant mixers. A wide variety of these torque transducers is commercially available, but most of these use slip rings for torque signal monitoring purposes. A slip ring assembly contains a series of insulated rings mounted on a shaft with a comparison series of insulated rings mounted in a case. High speed bearings between the shaft and the case permit the case to remain stationary while the shaft rotates. When installing these transducers on gun propellant

incorporators, they have to be enclosed in a nitrogen purged casing to prevent an arc between the transducer contact and the slip rings. A typical example of this type of transducer is known as a reaction type transducer.

The rotary transformer type in-line torque transducers do not use slip rings in their design. The main feature of this design is that either the primary or secondary winding of the transformer rotates. The rotating transformer transmits AC excitation voltage to a strain gauge bridge and the stationary one transfers the signal output to the non-rotating part of the transducer.

Another technique, more appropriate to the measurement of torque for gun propellant mixers, uses electrical resistance torque transducers. Strain gauges responding to shear stresses in shafts are used in this method. The strain gauges are usually wired in a full Wheatstone bridge arrangement on these shafts and shear strain linearly proportional to the torque applied is induced in the strain gauges which converts the strain into an electrical output. This signal is transmitted from the rotating shaft to the stationary housing where it is read by three different methods; slip rings, a rotary transformer and an RF telemetry system. The rotary transformer and RF telemetry are the preferred signal monitoring methods, but all are expensive.

#### 5.5 Roll mill performance results

The results in figure 19(a) show peak power and energy increasing with the number of passes. The idling power for this particular cycle was 1.58 kW and after the eighth pass, fluctuations were observed with the peak power readings but the cumulative energy remained steady with a minimal increase in value. The integrated power values were printed out as energy values by the processor with integration above the set threshold value set at ten percent above idling power value (see Appendix II). The total energy of this particular cycle was recorded as 146 kJ.

Figure 19(b) show the results from a thirty one pass trial. The idling power was measured as 1.71 kW and as observed earlier (figure 16) the power measurements showed fluctuations with peak power matching or in phase with pass energy values. At the final stages of the trial the peak power readings remained constant at 9.38 kW. It is to be noted that if the idling power value is added to the peak power value of 9.38 kW, a total value of 11.09 kW would be obtained but the power transducer used can only measure up to 10.8 kW. Hence modification is required for the power transducer to measure power higher than 9.33 kW. A 15 kW maximum power transducer has been recommended for installation on the roll mill motor in the near future.

In figure 19(c) the results are shown from a forty pass trial. The idling power remained at 1.58 kW. but peak power remained below idling power for twenty three passes. Comparing figures 19(a) to (c), it is observed that although the idling power in both cases is similar, the peak power value shows a different trend. The change could be ascribed to the propellant material in use which may vary in quality or thickness during each pass and the effect of ambient temperature may have influenced results from one trial to another.

If direct comparisons are to be made between trials, the idling power levels, material composition and quality, and thickness should be constant. The ambient temperature must be within specified narrow limits and be constant for each trial. The idling power values should be monitored every ten passes on each trial so as to record any fluctuations during trials.

## 6. CONCLUSIONS AND RECOMMENDATIONS

In examining the effectiveness and suitability of load sensing systems on gun propellant processing equipment the following conclusions were reached.

- (1) The interface strain gauge load cell was found to be affected by the temperature change in the mixer bowl. It was considered that this could be due to the thermal expansion of the bowl or the T piece attached to mixer bowl.
- (2) Both the Hioki clamp on power measurements and the hydraulic pressure measurement from the incorporator proved to be good techniques for measuring work input in gun propellant incorporators. Pressure measurement will require two pressure transducers, one to measure the forward and the other, the reverse mode of mixing.
- (3) In-line torque transducers are expected to be an efficient method of torque measurement on incorporators.
- (4) The Hawker de Havilland meter used on the rolling mill was a reliable method of measuring work input by the rolls. This method of measurement could be extended to the incorporators.

## 7. ACKNOWLEDGEMENTS

The authors wish to acknowledge Mr M. Bone, Mr J. Levers and Mr S. Simmonds for their assistance and technical suggestions made in the preparation of this report.

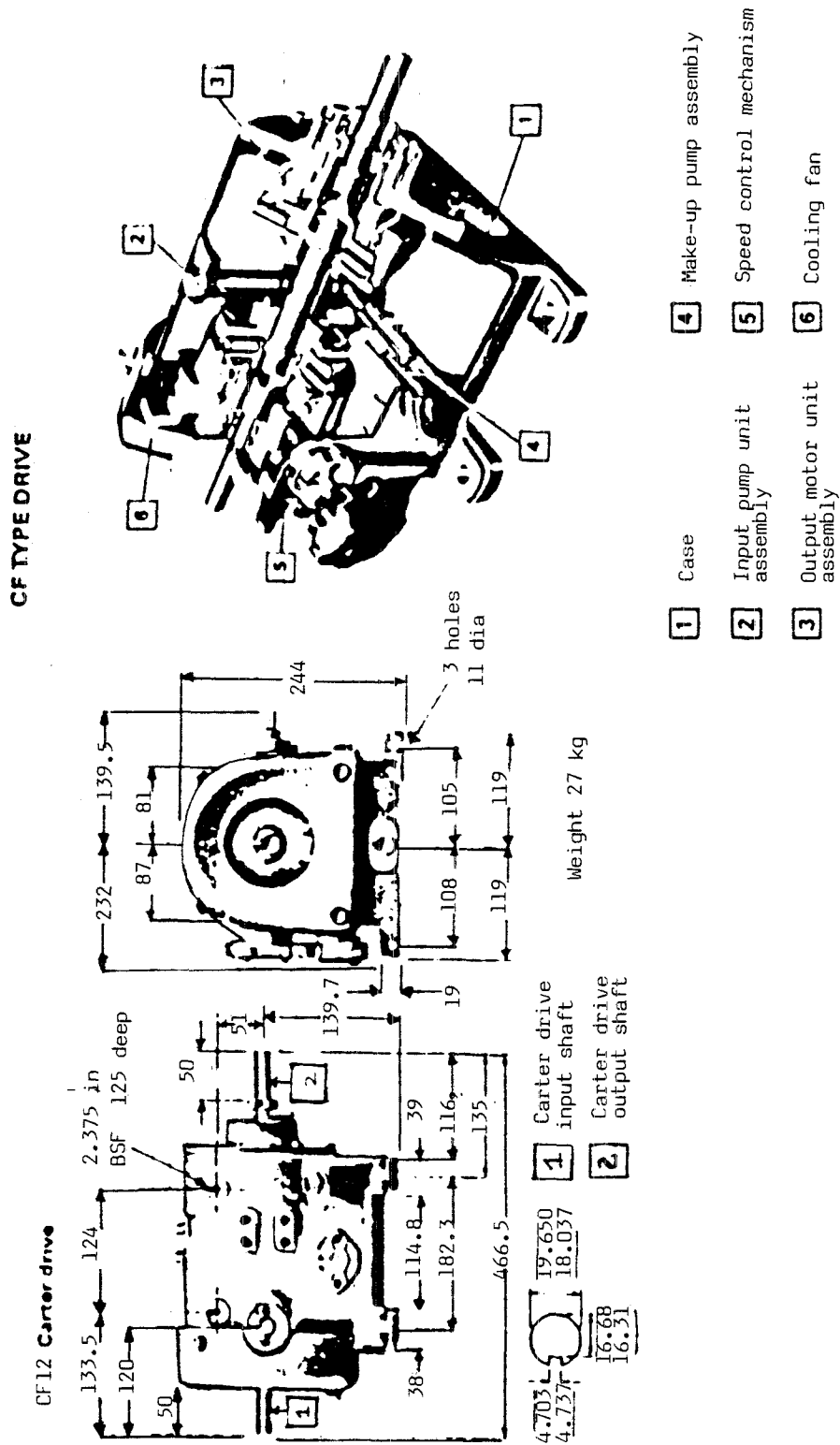


Figure 1. Radial piston pump

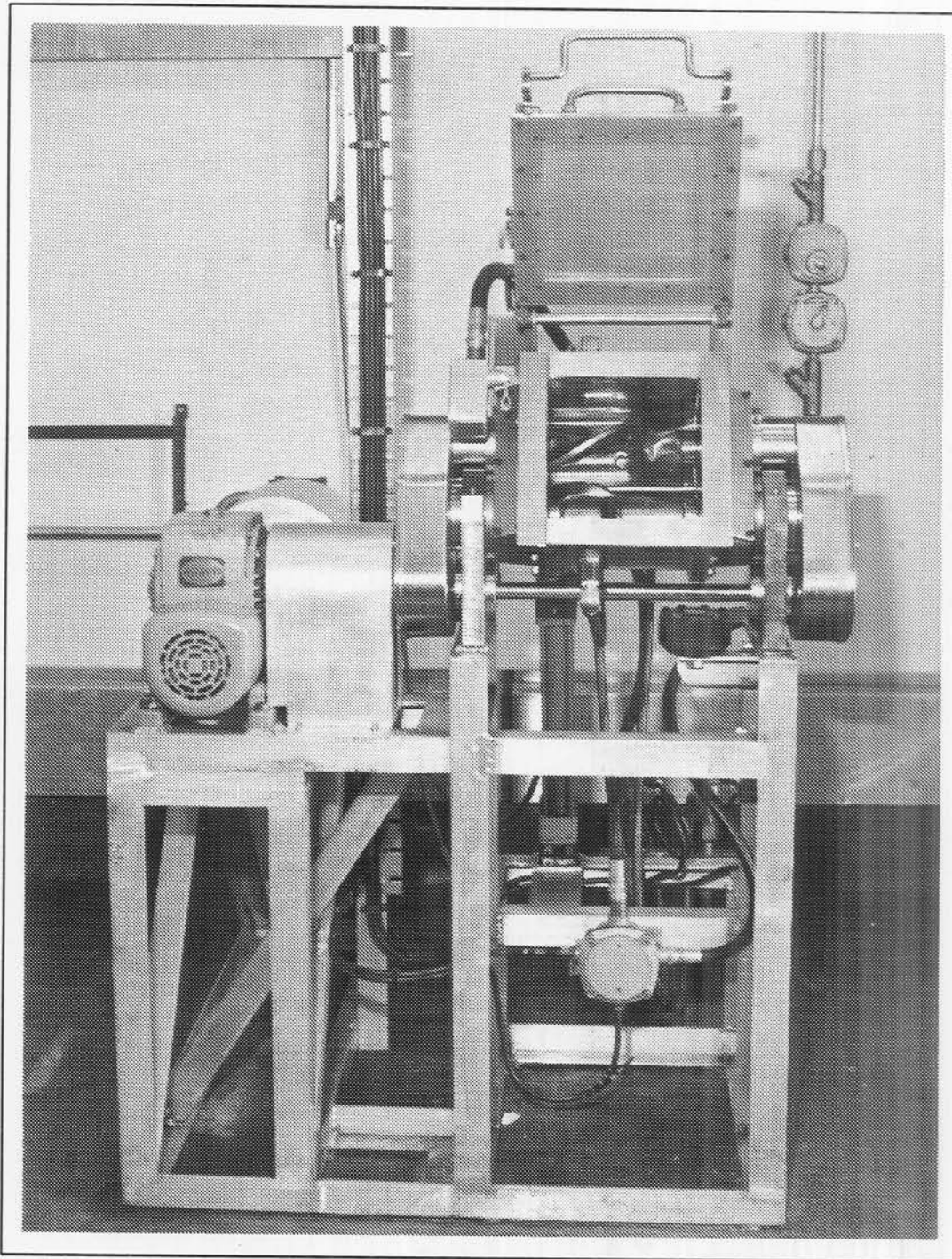


Figure 2. 1 kg incorporator

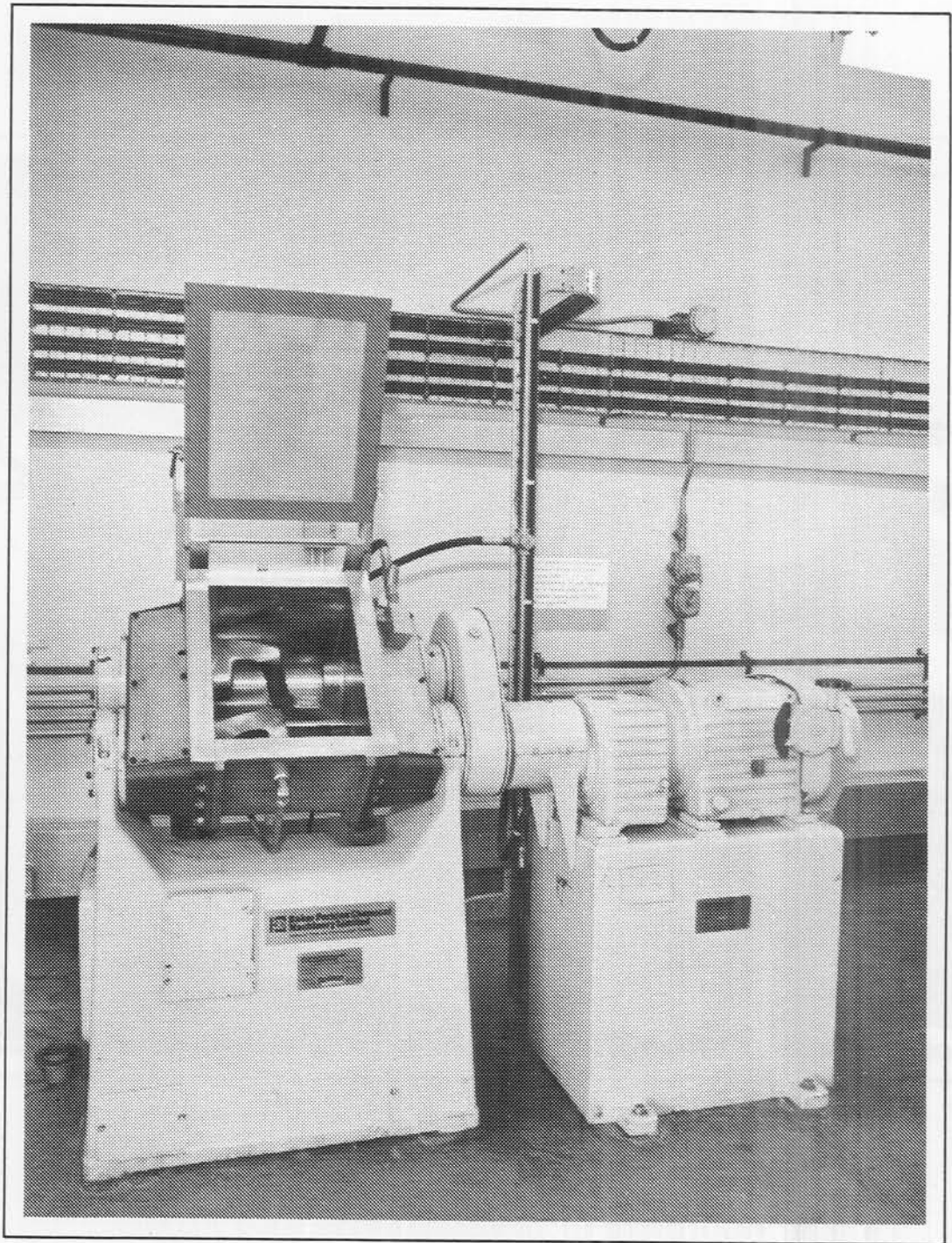


Figure 3. 5 kg incorporator



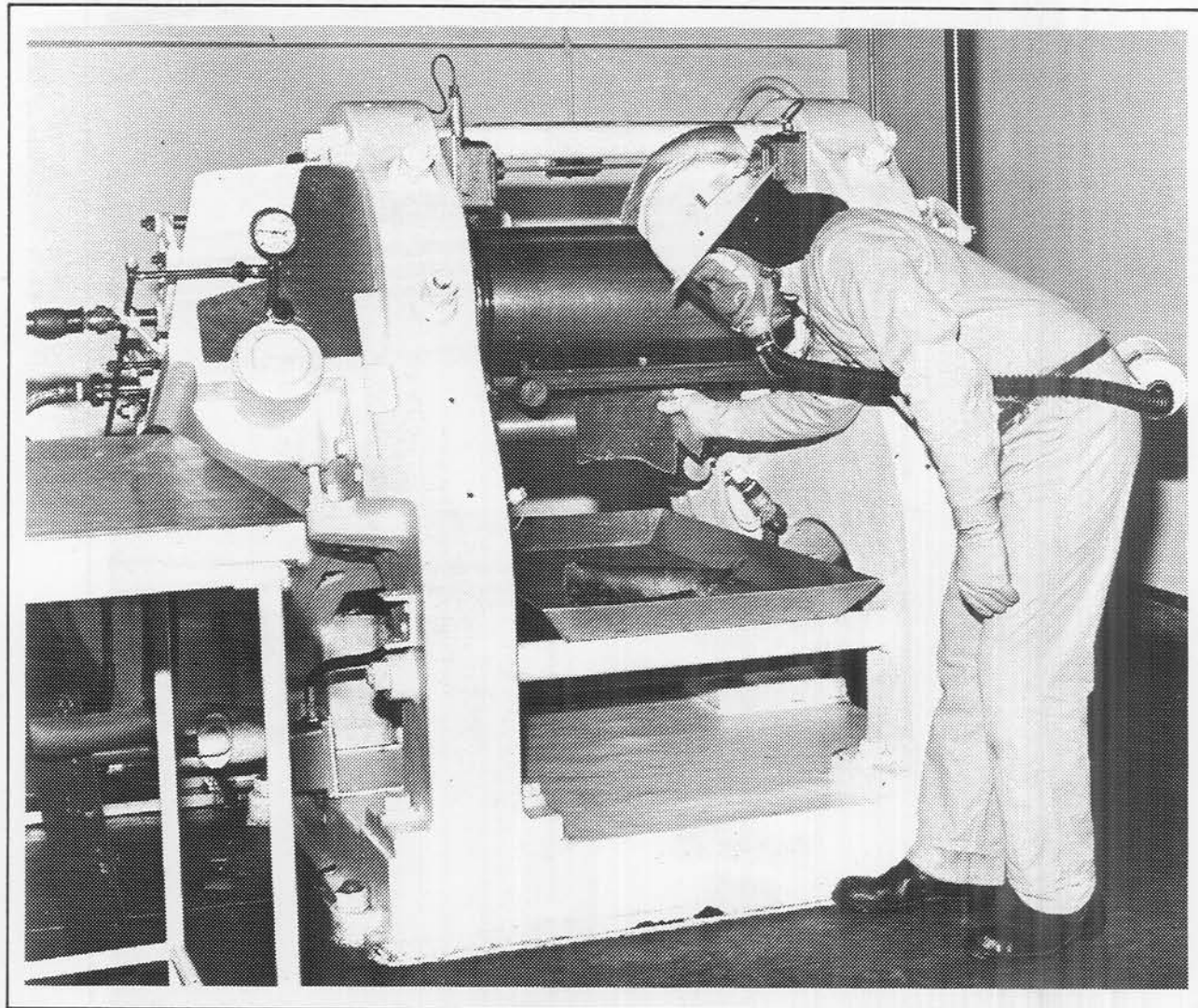


Figure 4. Roll mill

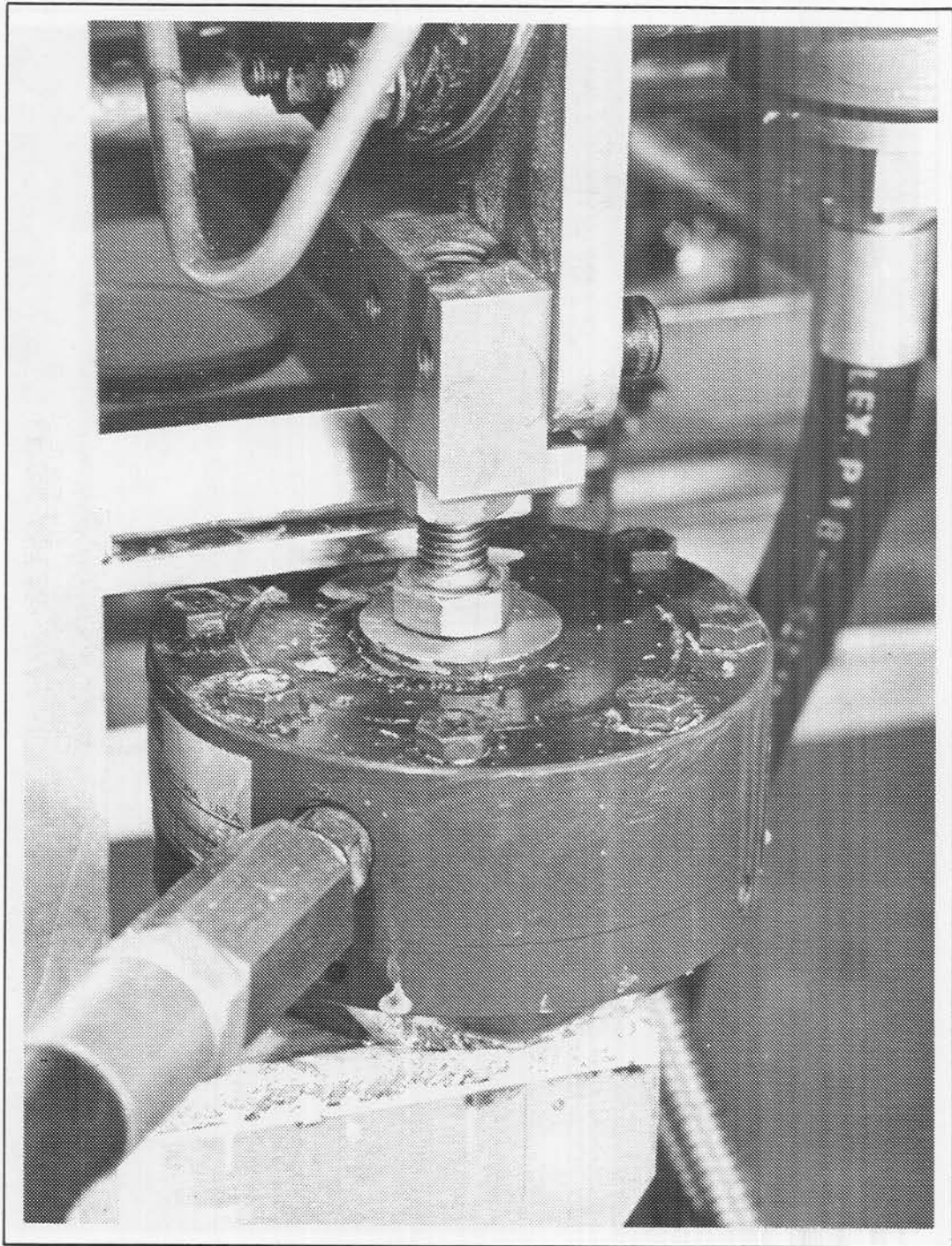


Figure 5. Load cell



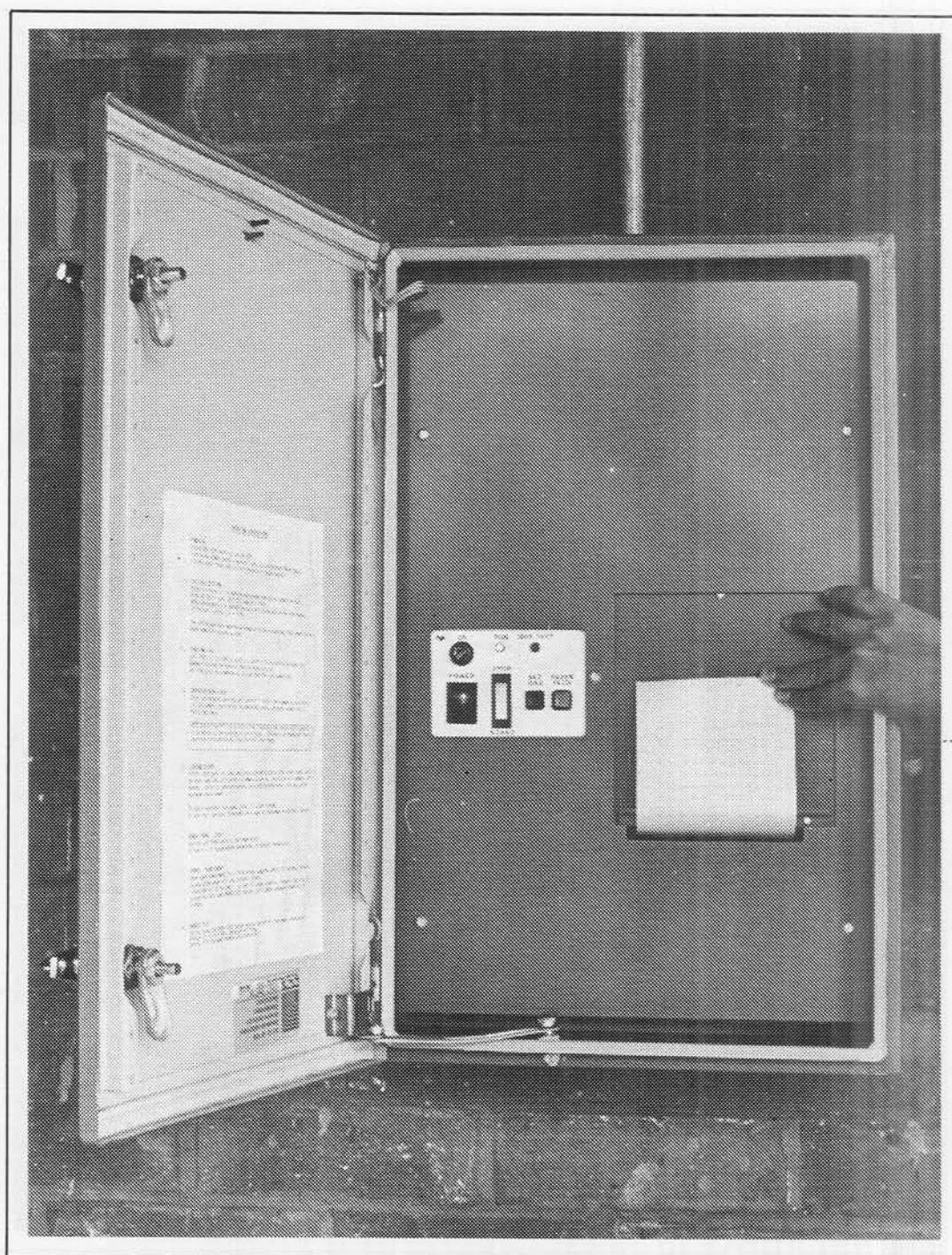


Figure 6. Roll mill power monitor

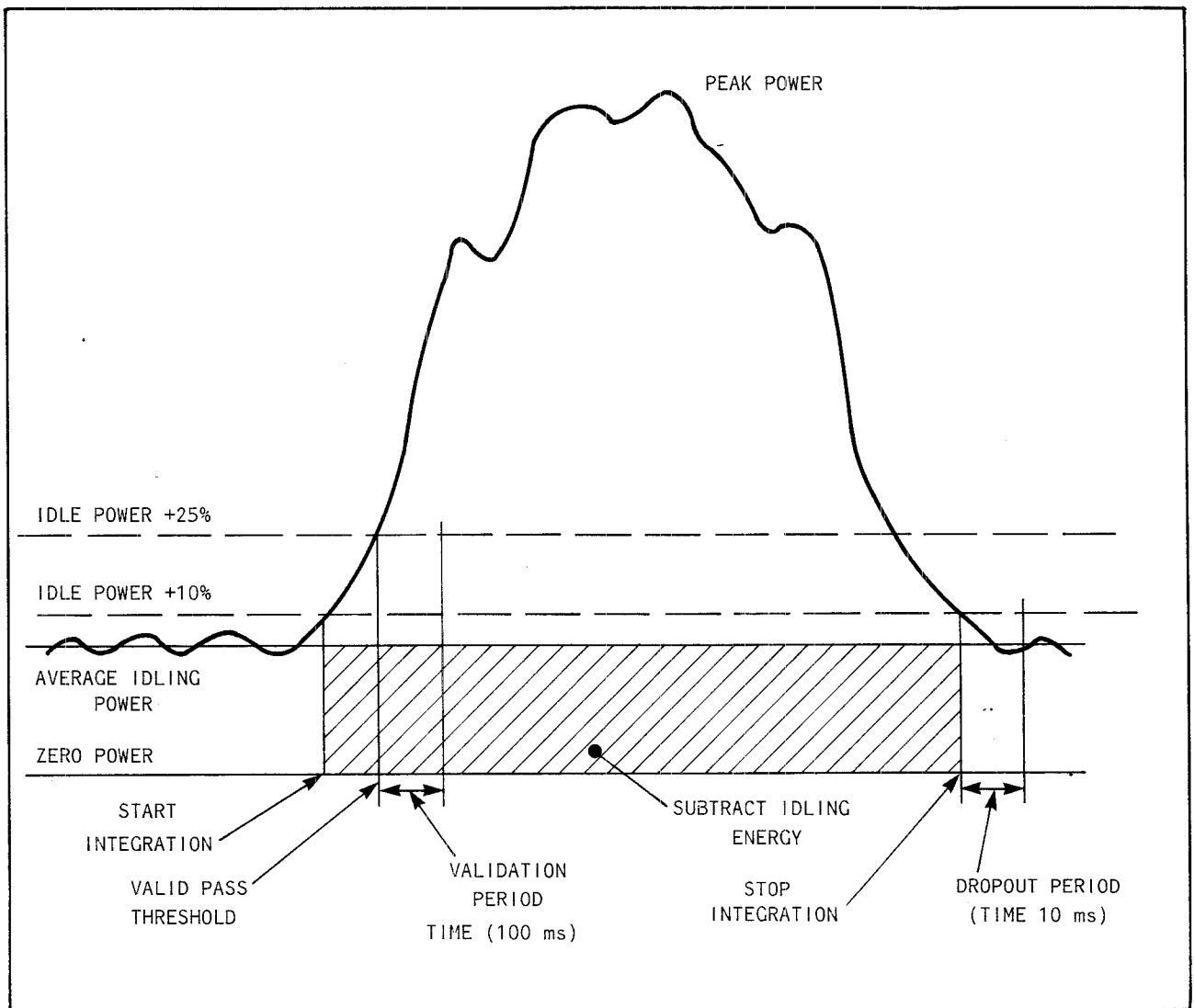


Figure 7. Pass detection diagram

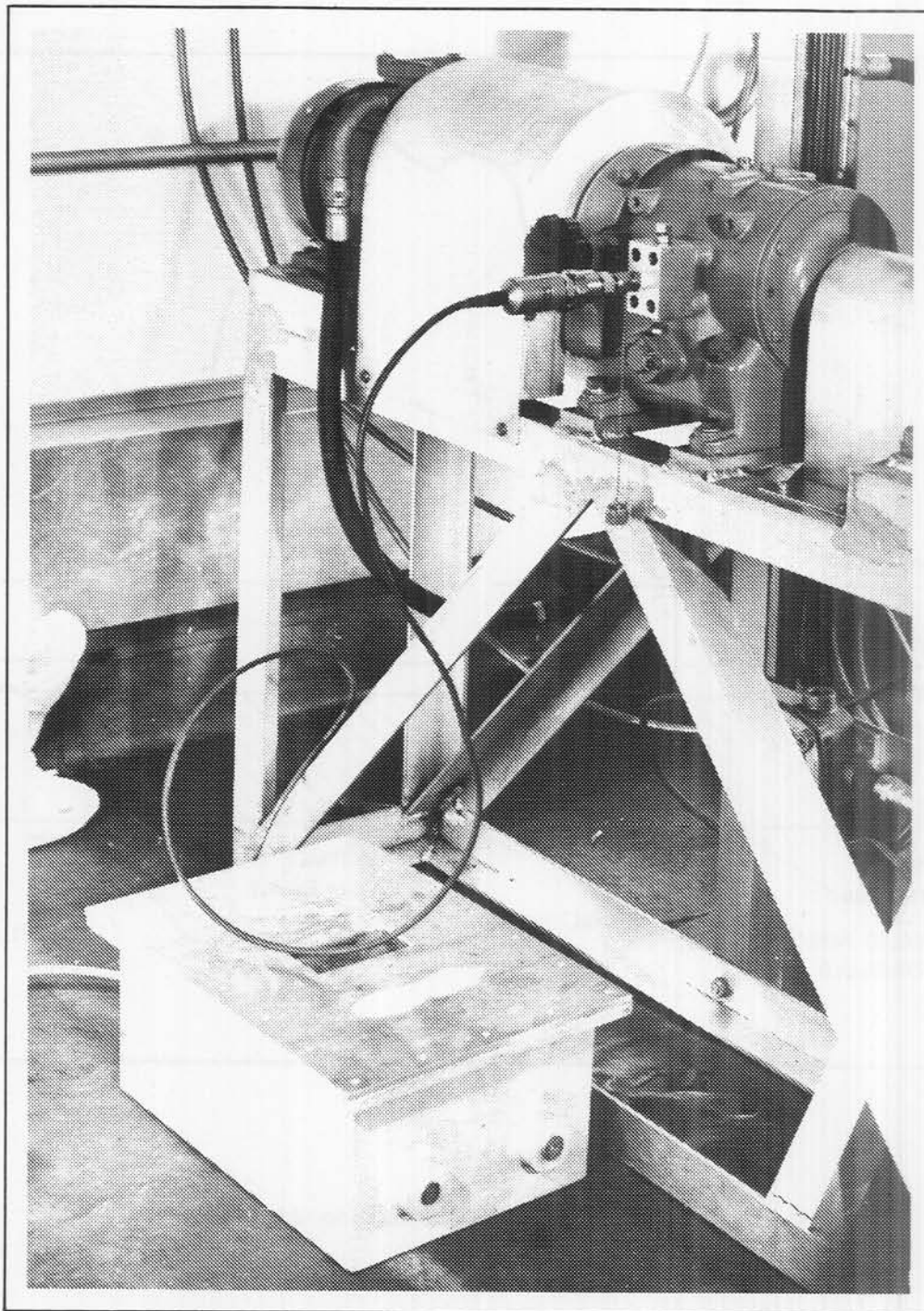
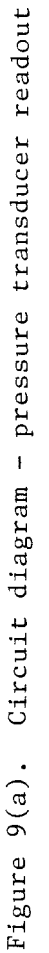


Figure 8. Pressure transducer on 1 kg mixer hydraulic drive



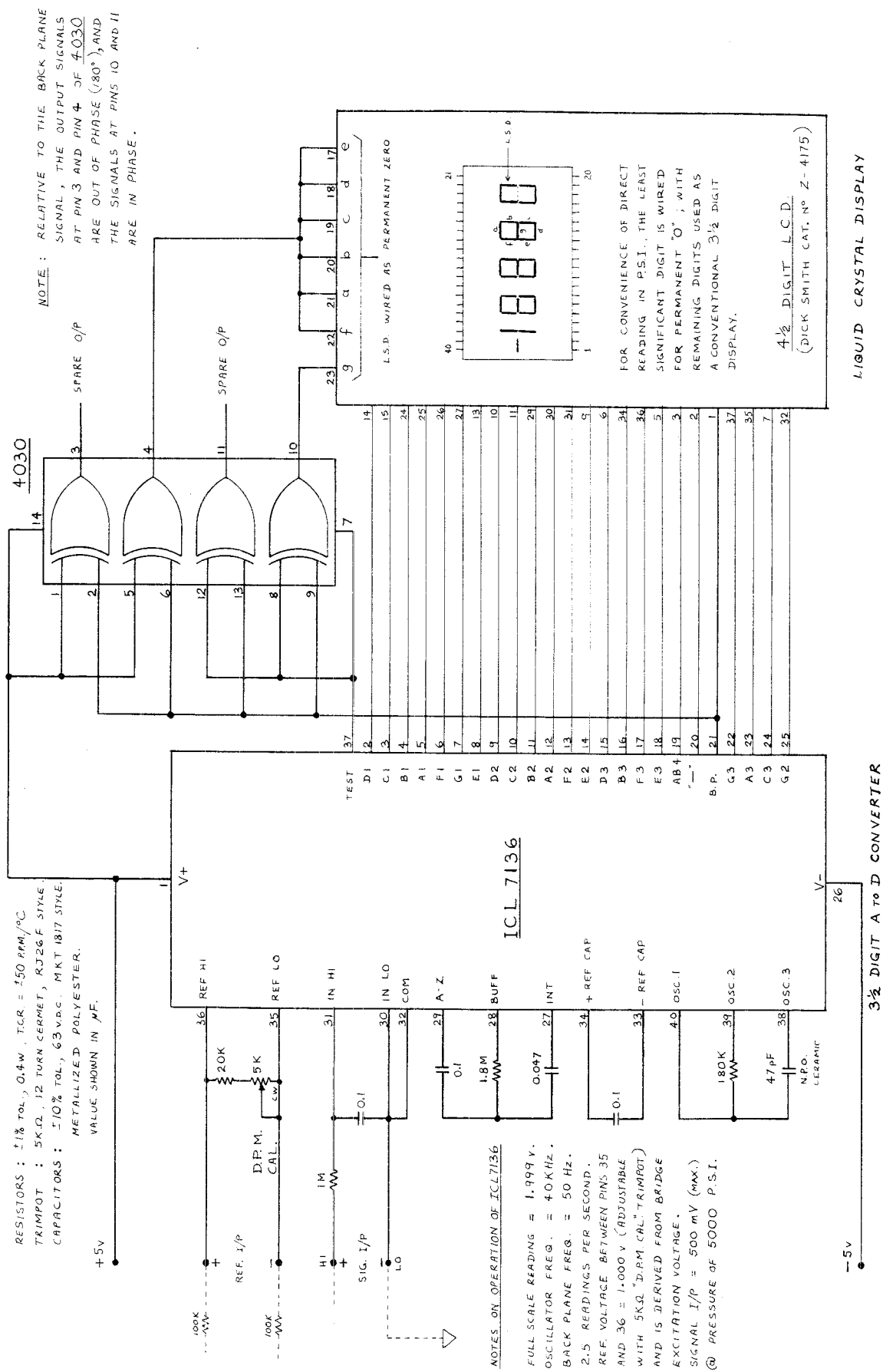
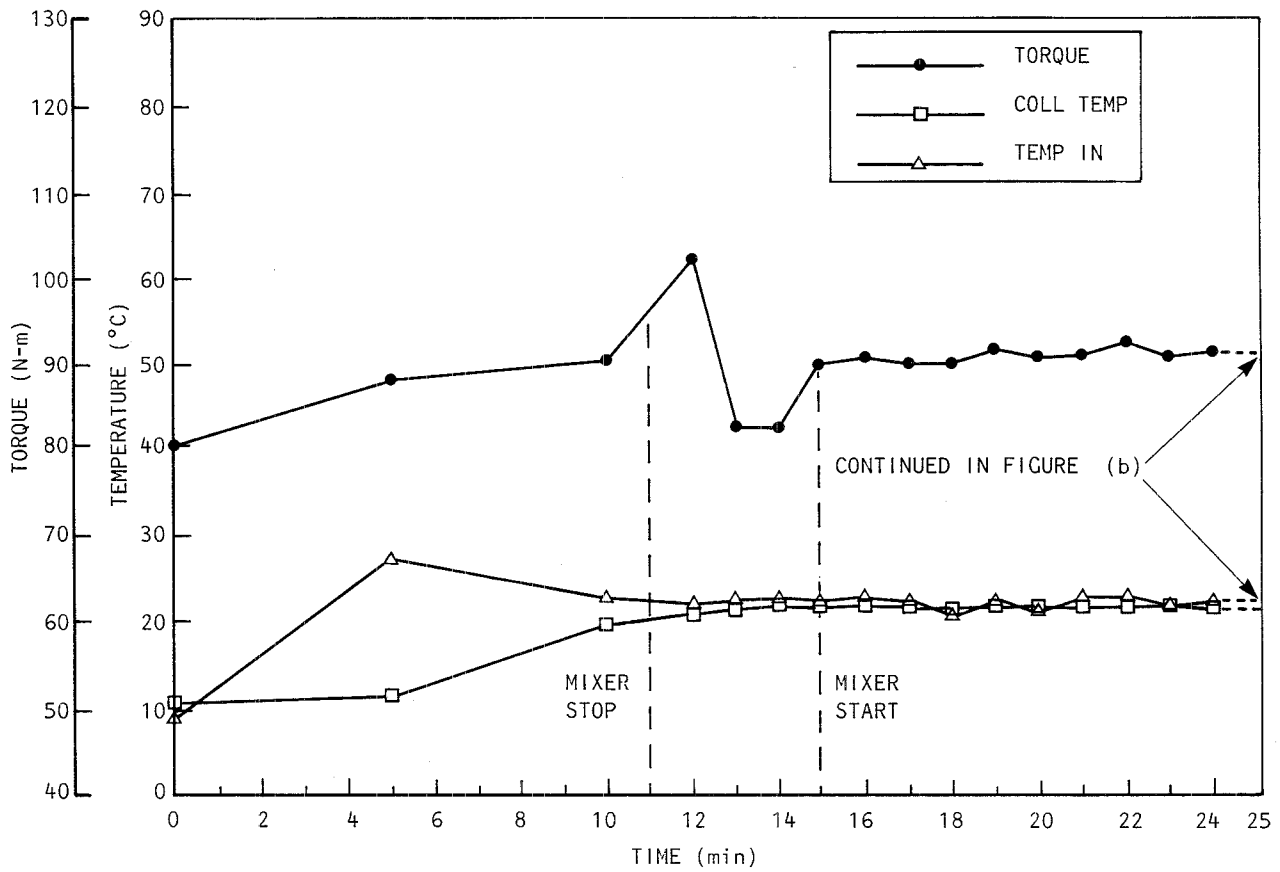


Figure 9(b). Circuit diagram - A to D converter and display board (DPM)

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(a)

Figure 10. Torque, temperature vs time of mixing (1 kg mixer)

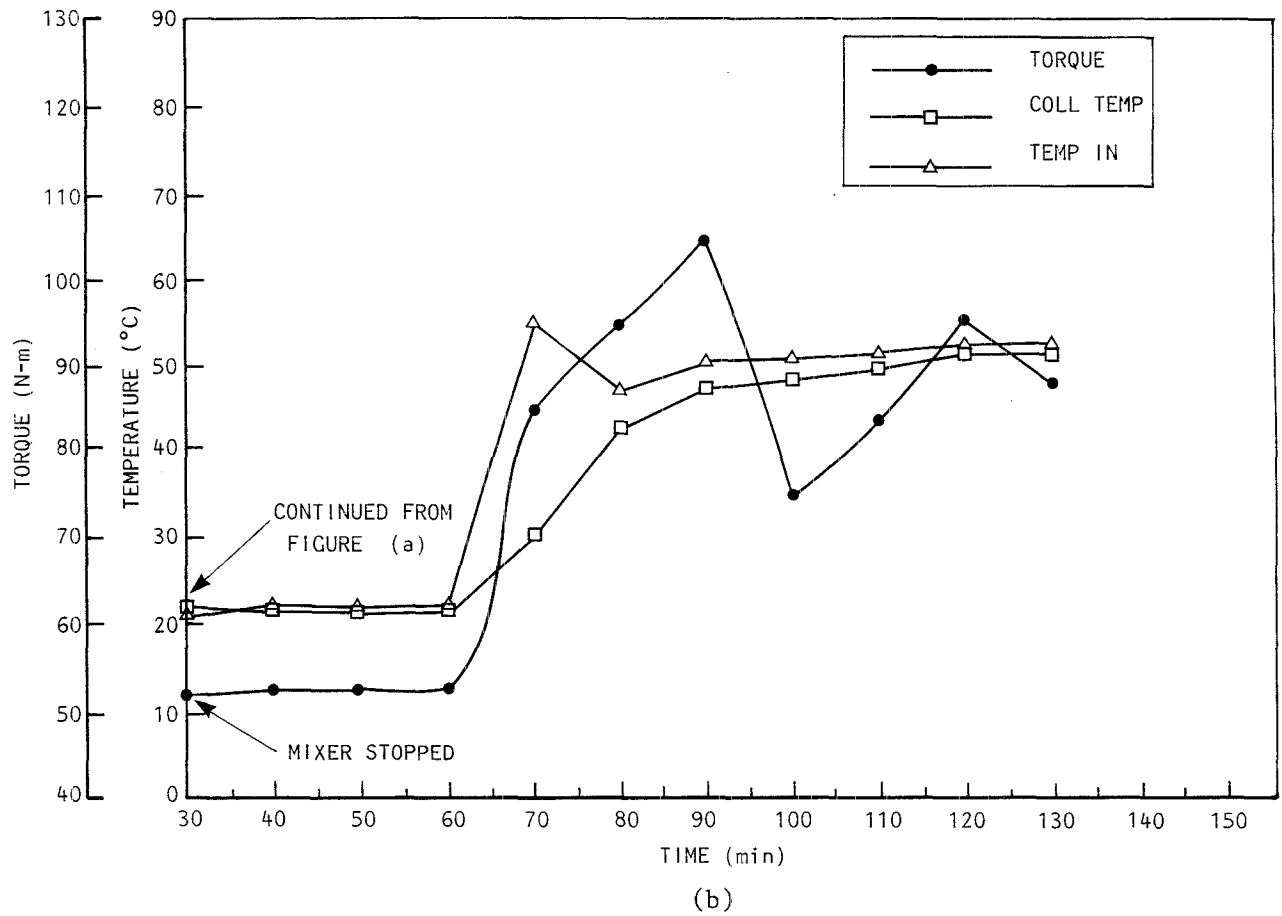


Figure 10(Contd.).



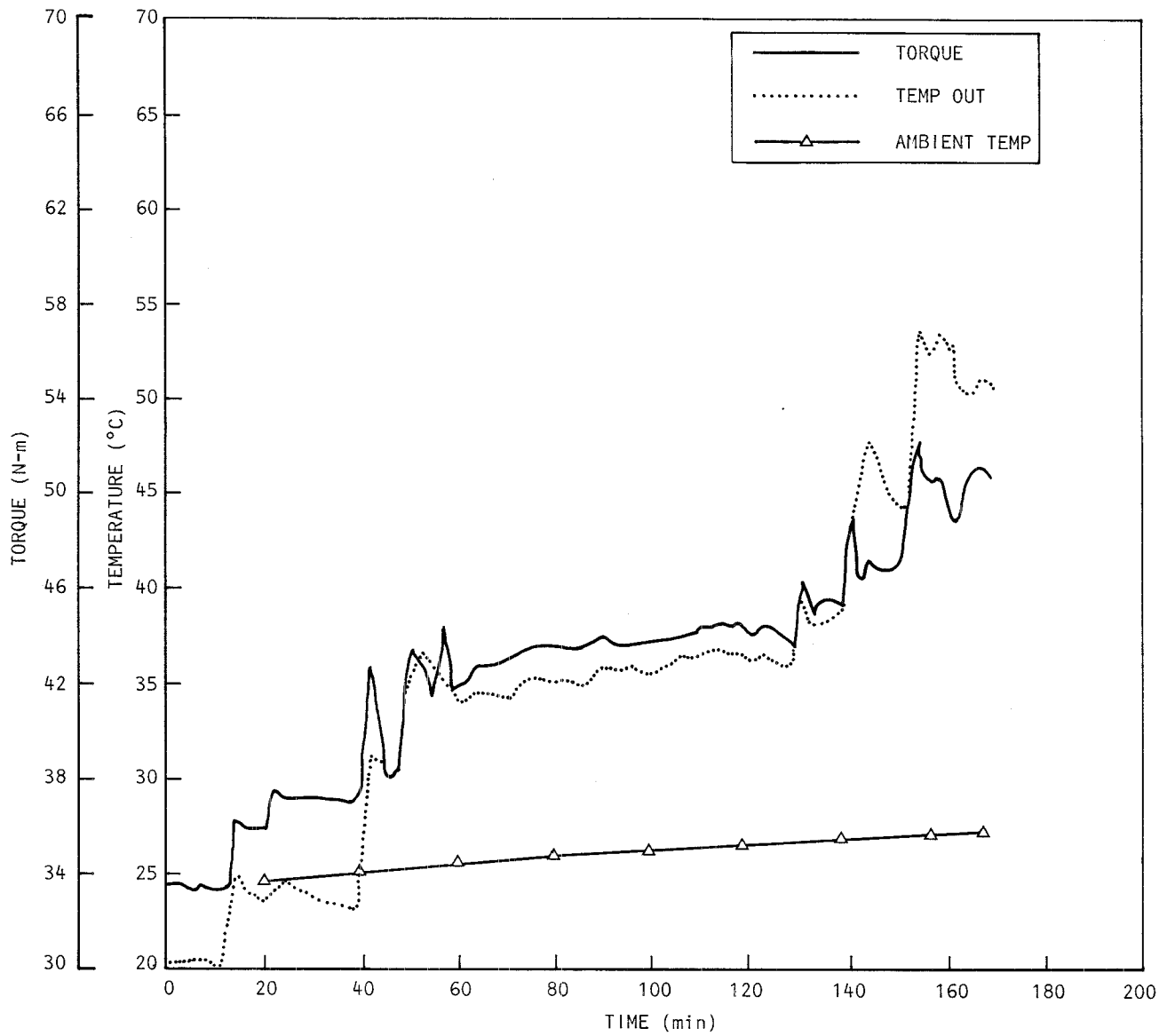


Figure 11(a). Temperature-torque measurements (1 kg mixer)

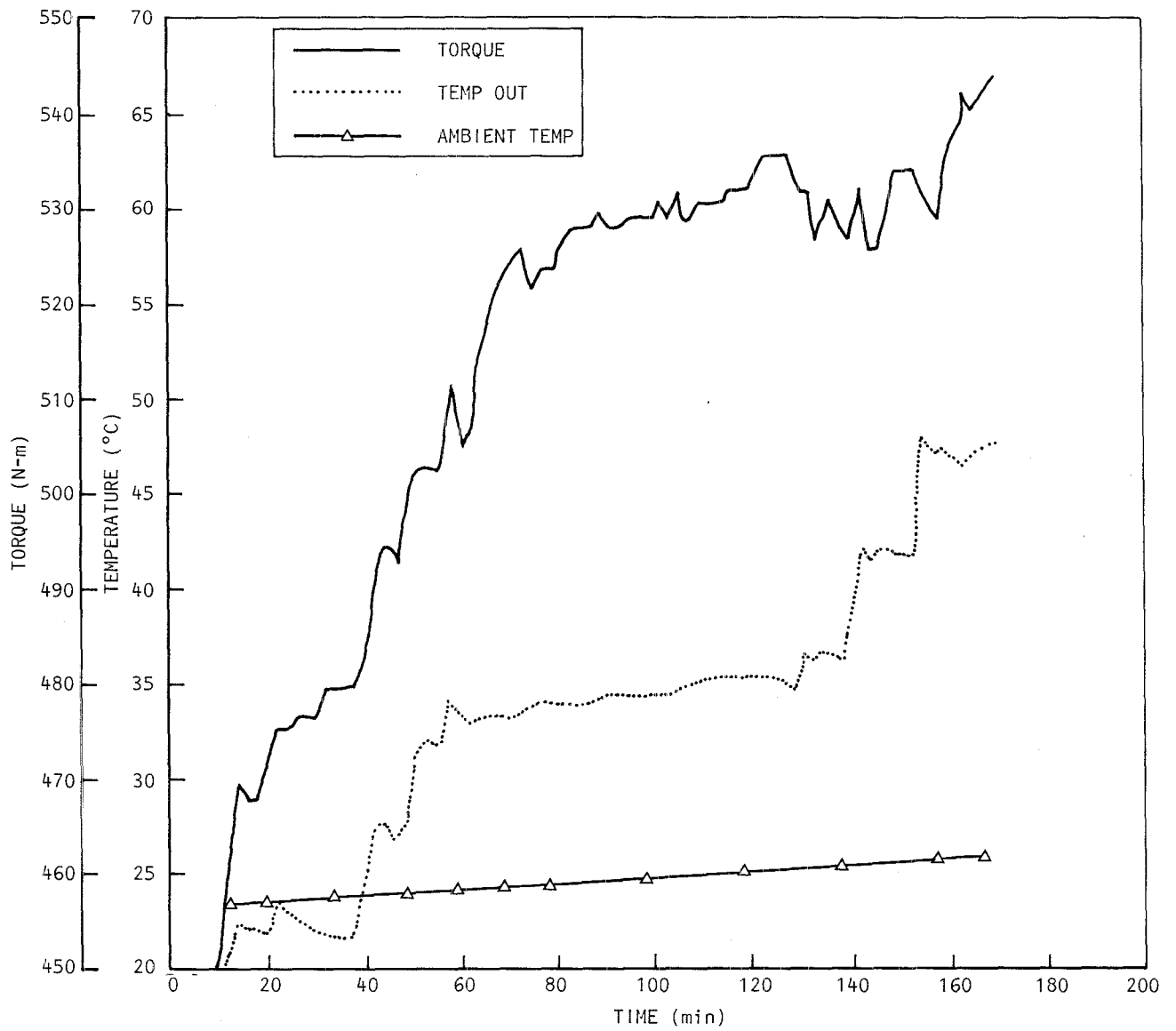


Figure 11(b). Temperature-torque measurements, mixer stationary (1 kg mixer)

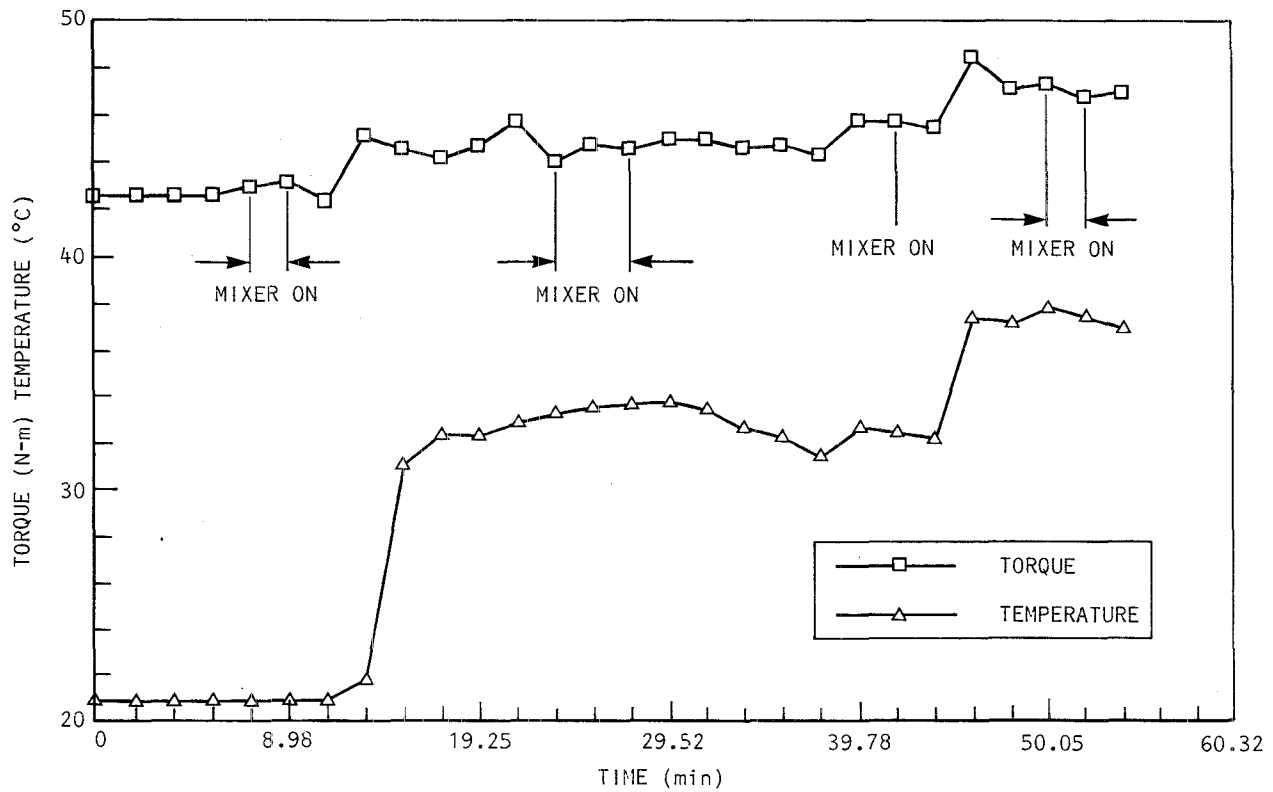


Figure 12. Temperature-torque studies, mixer on and off (1 kg mixer)

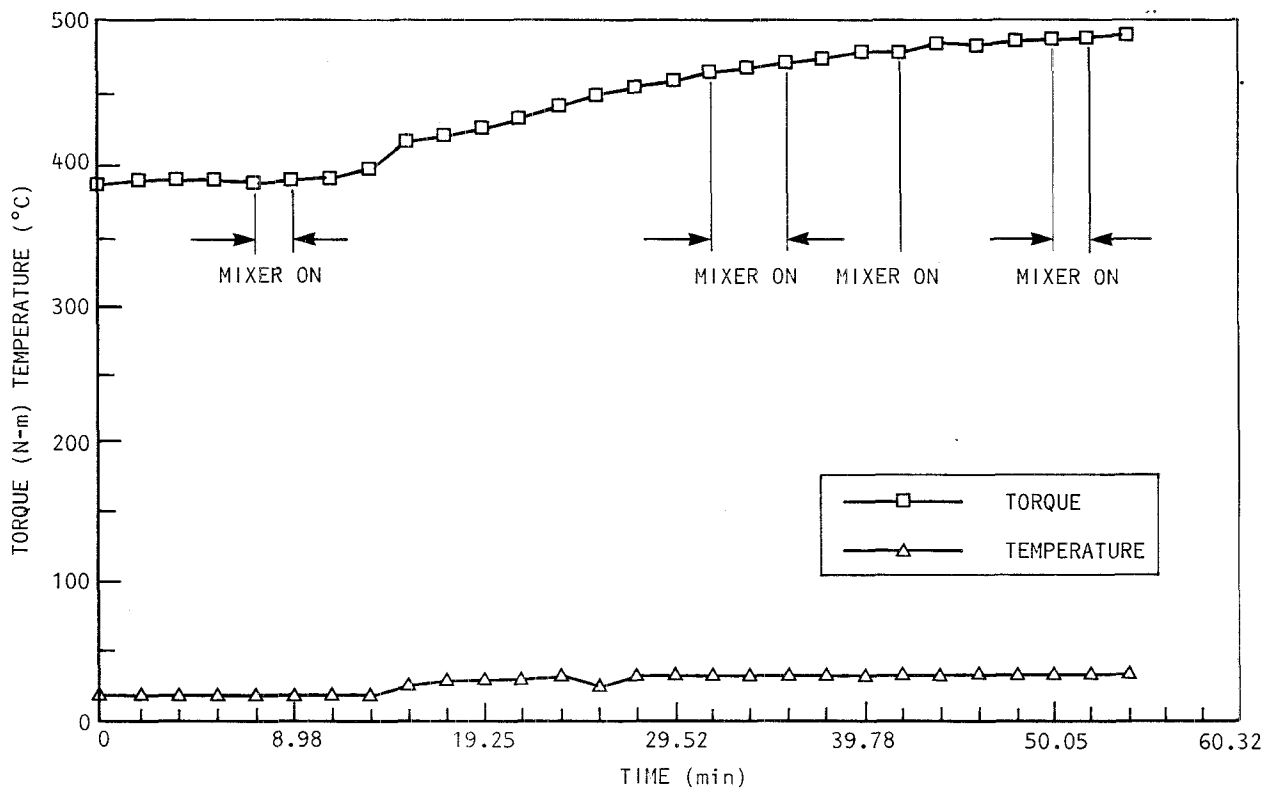


Figure 13. Temperature-torque studies, mixer on and off (5 kg mixer)

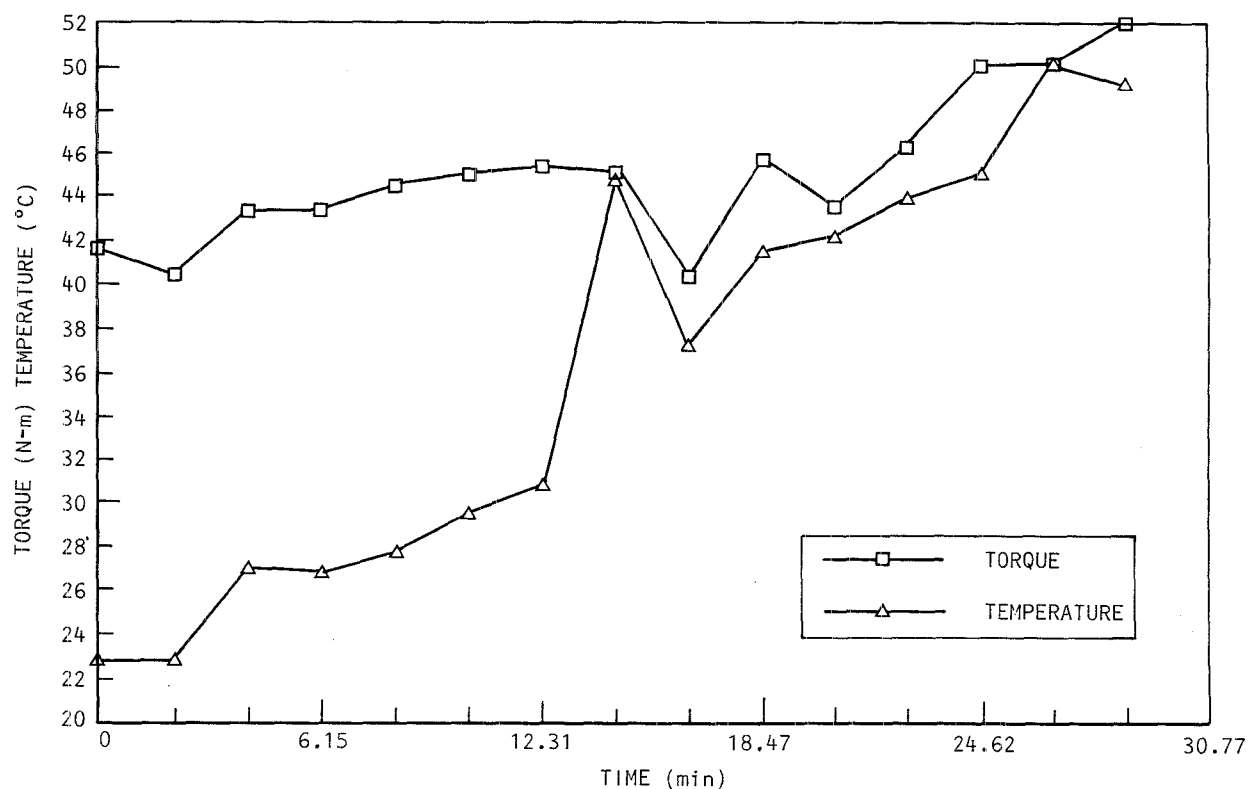


Figure 14. Continuous operation without load (1 kg mixer)

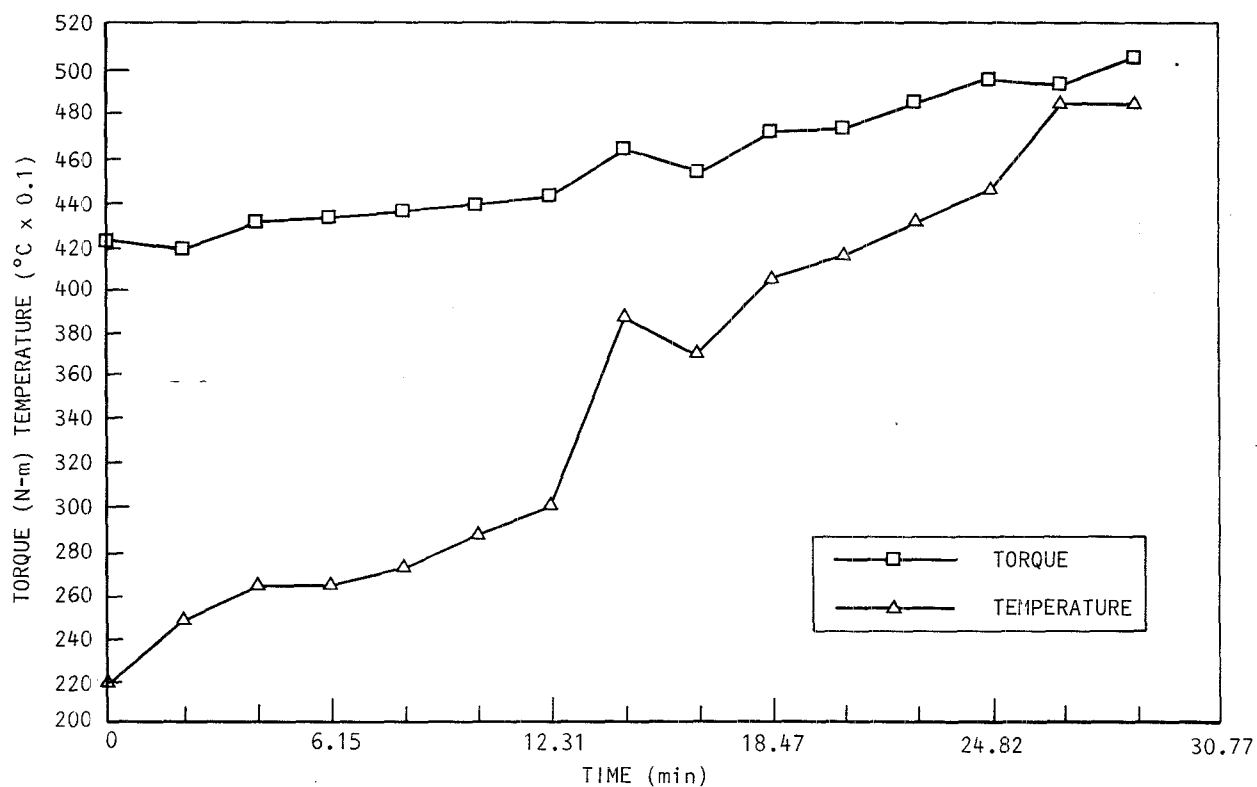


Figure 15. Continuous operation without load (5 kg mixer)

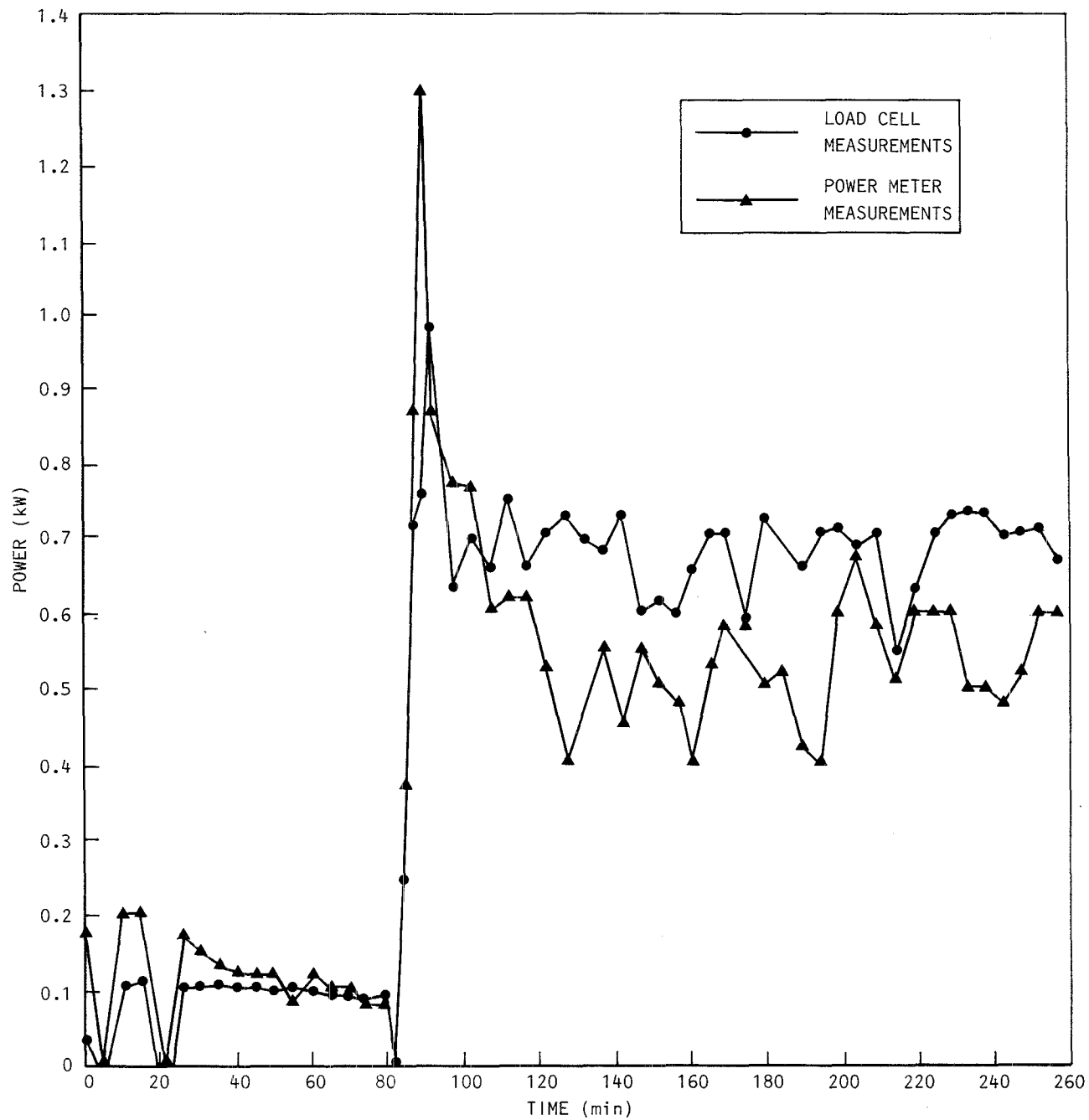
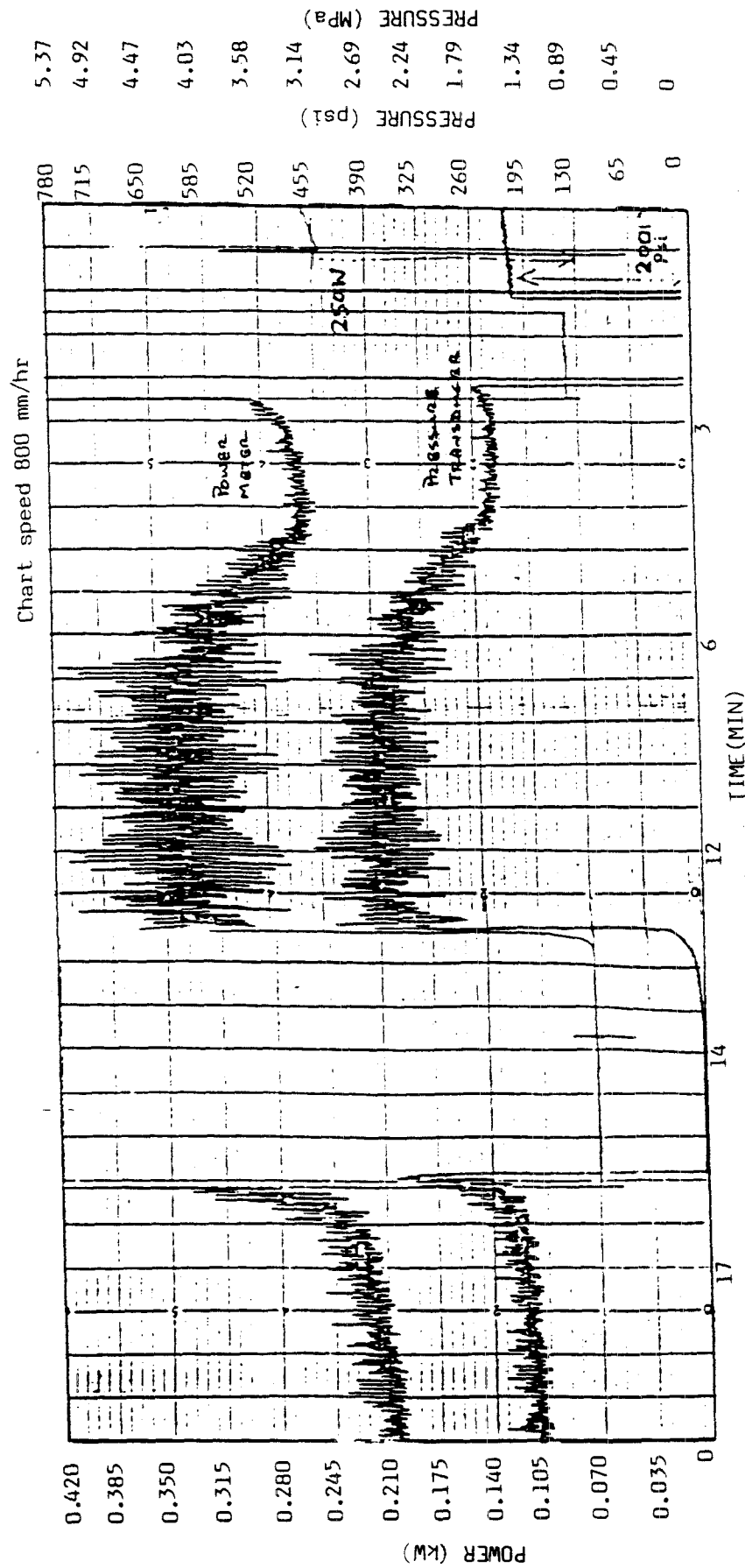
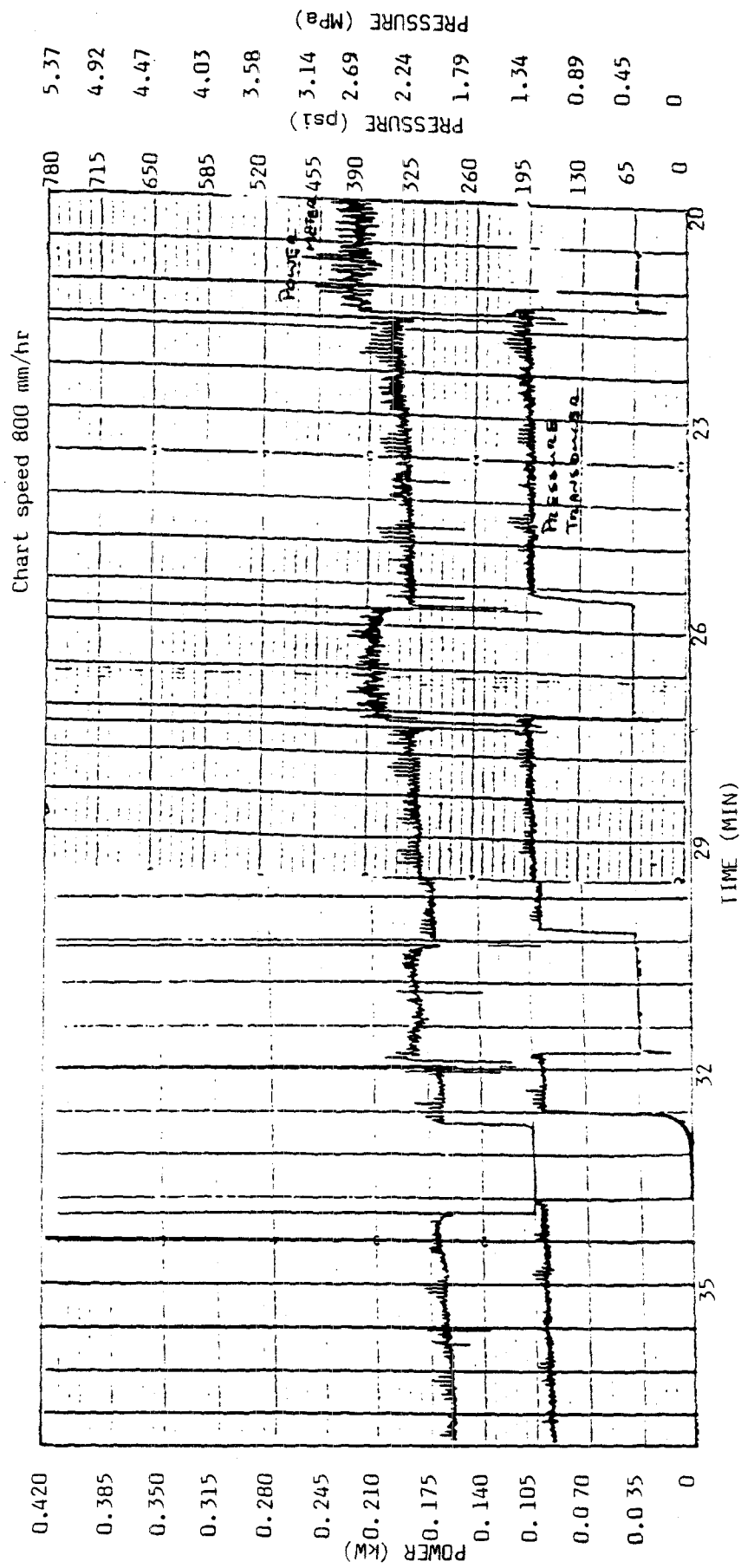


Figure 16. Load cell and power meter measurements (5 kg gun propellant mix)



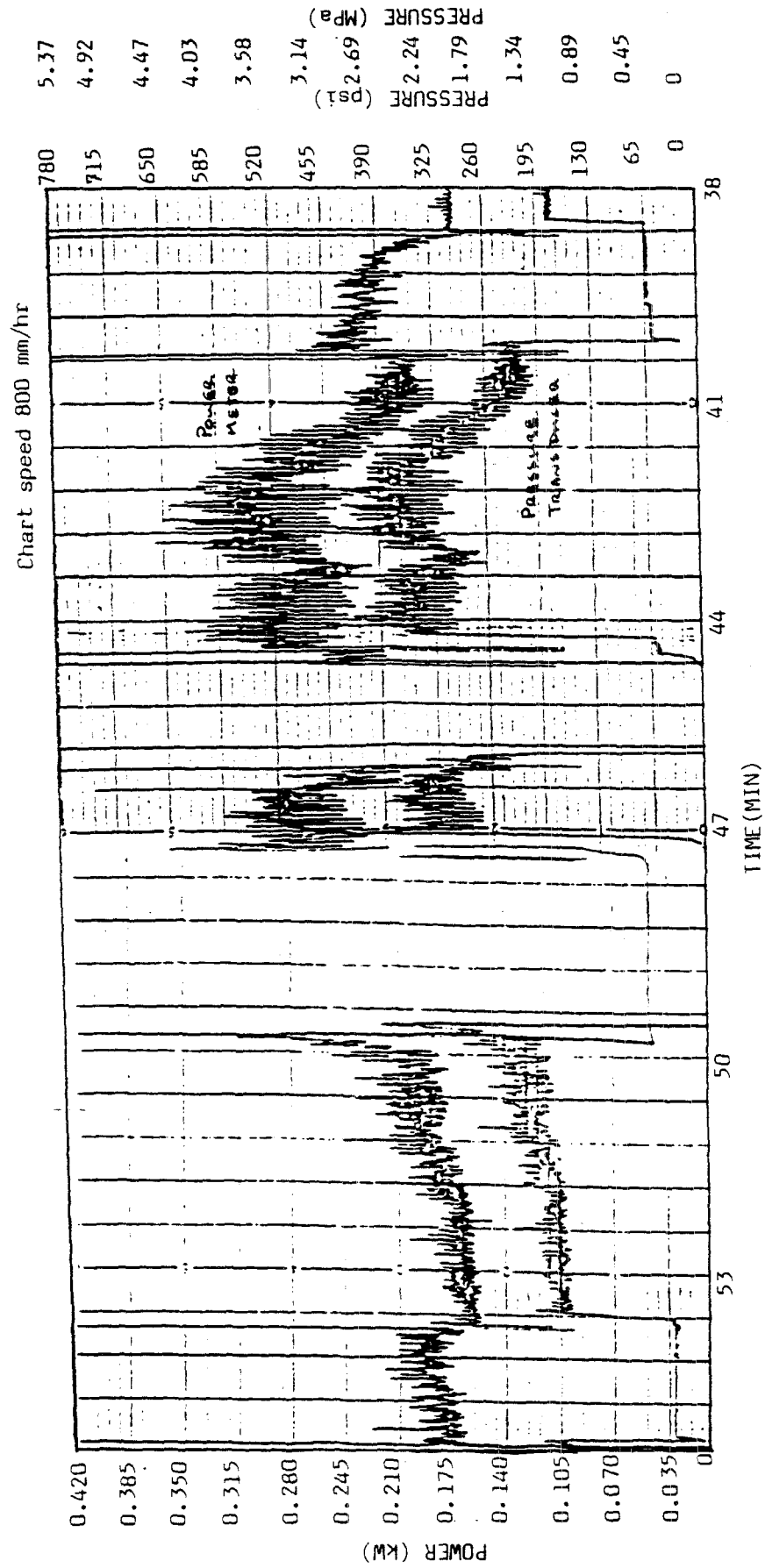
(a)

Figure 17. Pressure transducer and power meter measurements during gun propellant mixing operation (1 kg mixer)



(b)

Figure 17(Contd.).



(c)

Figure 17(Contd.).



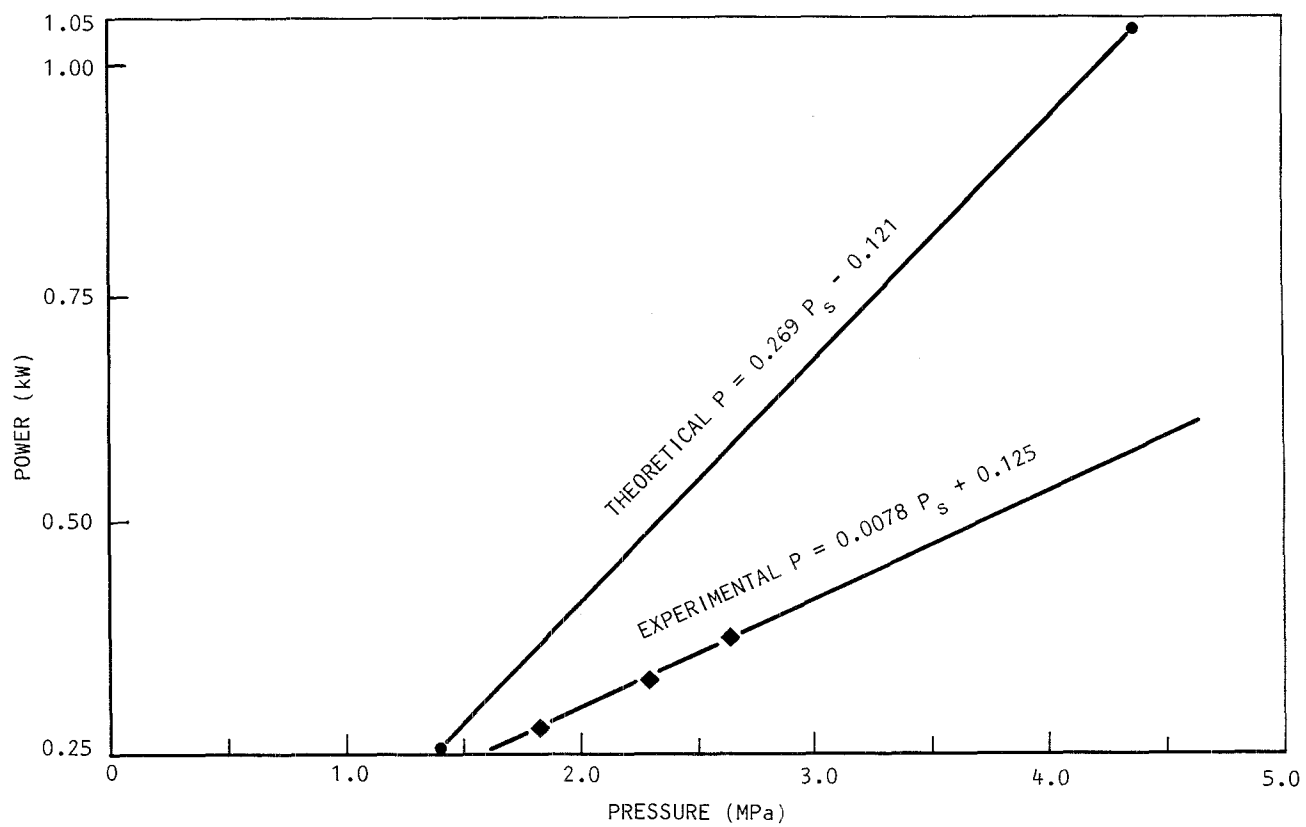
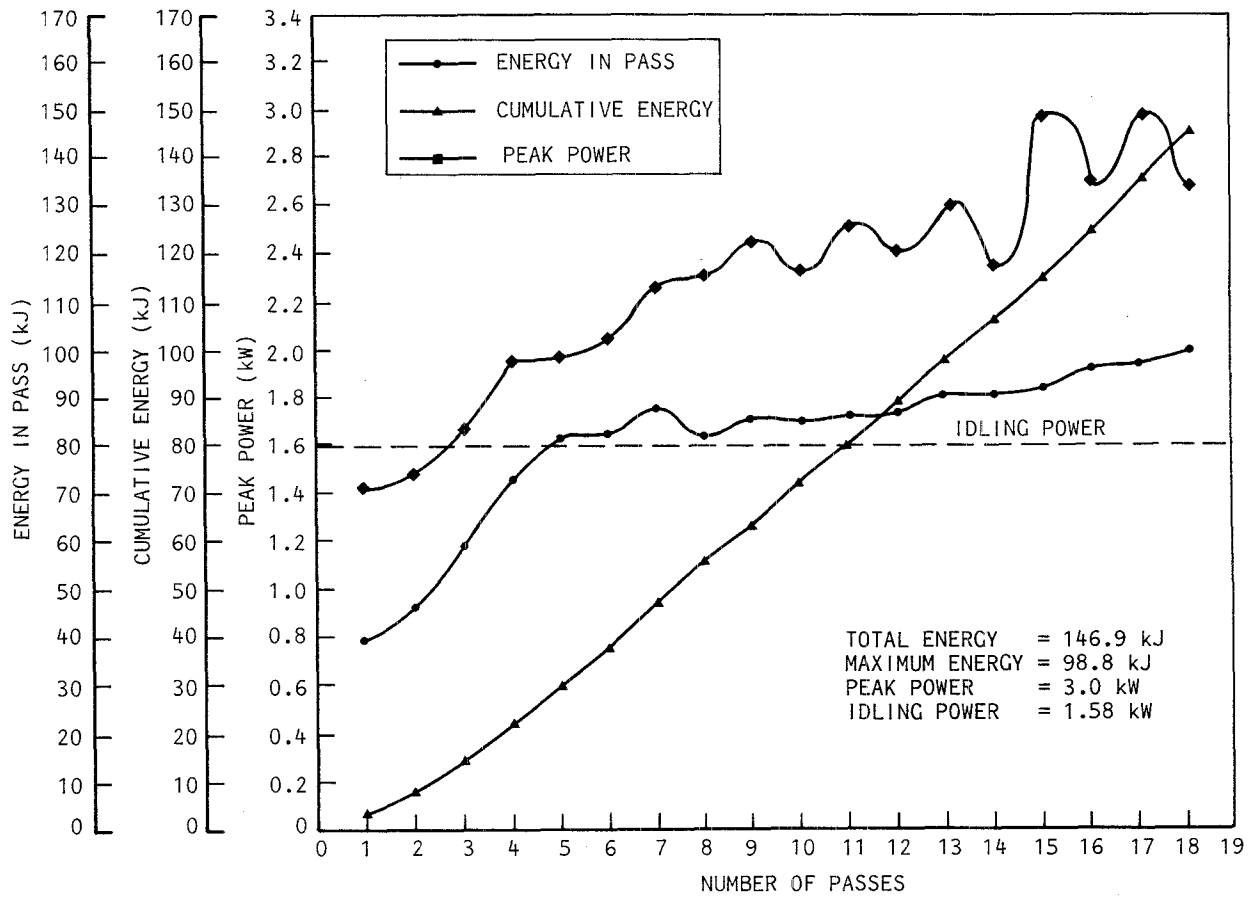
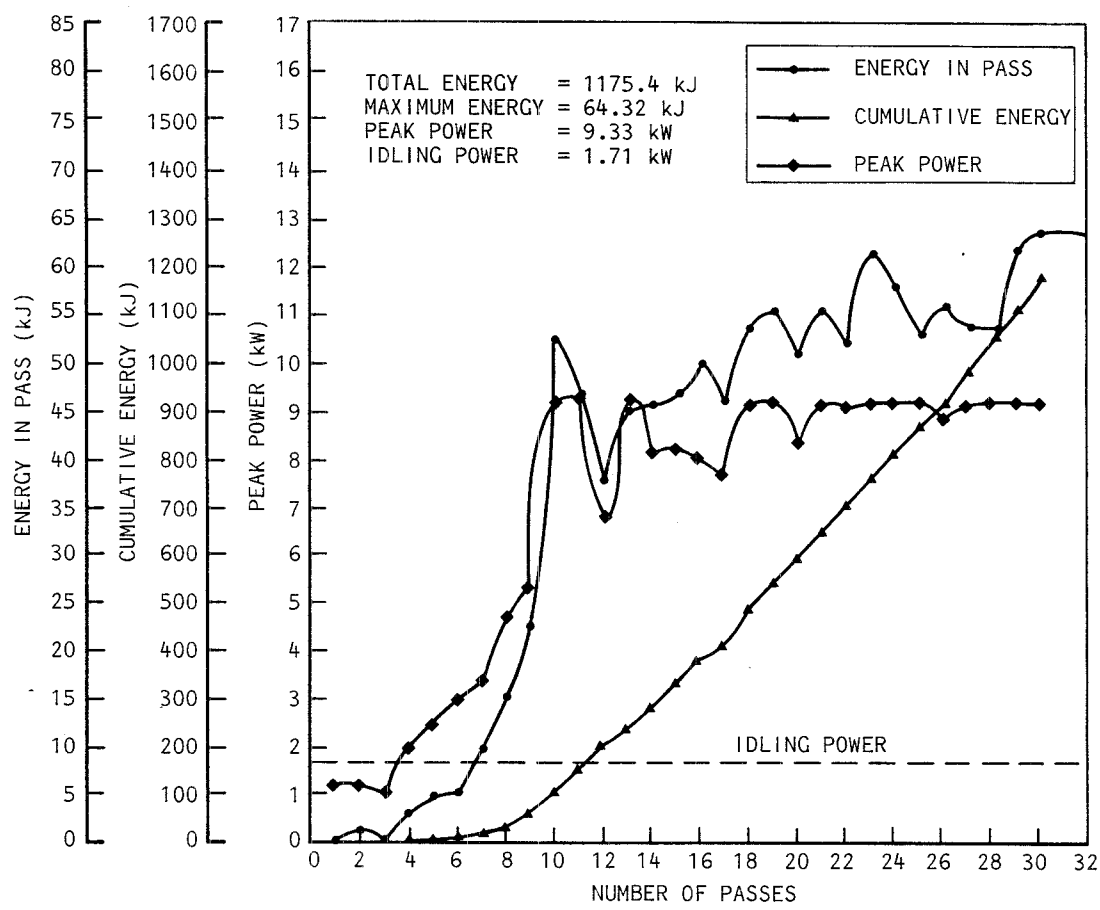


Figure 18. Hydraulic pressure versus motor power relationship



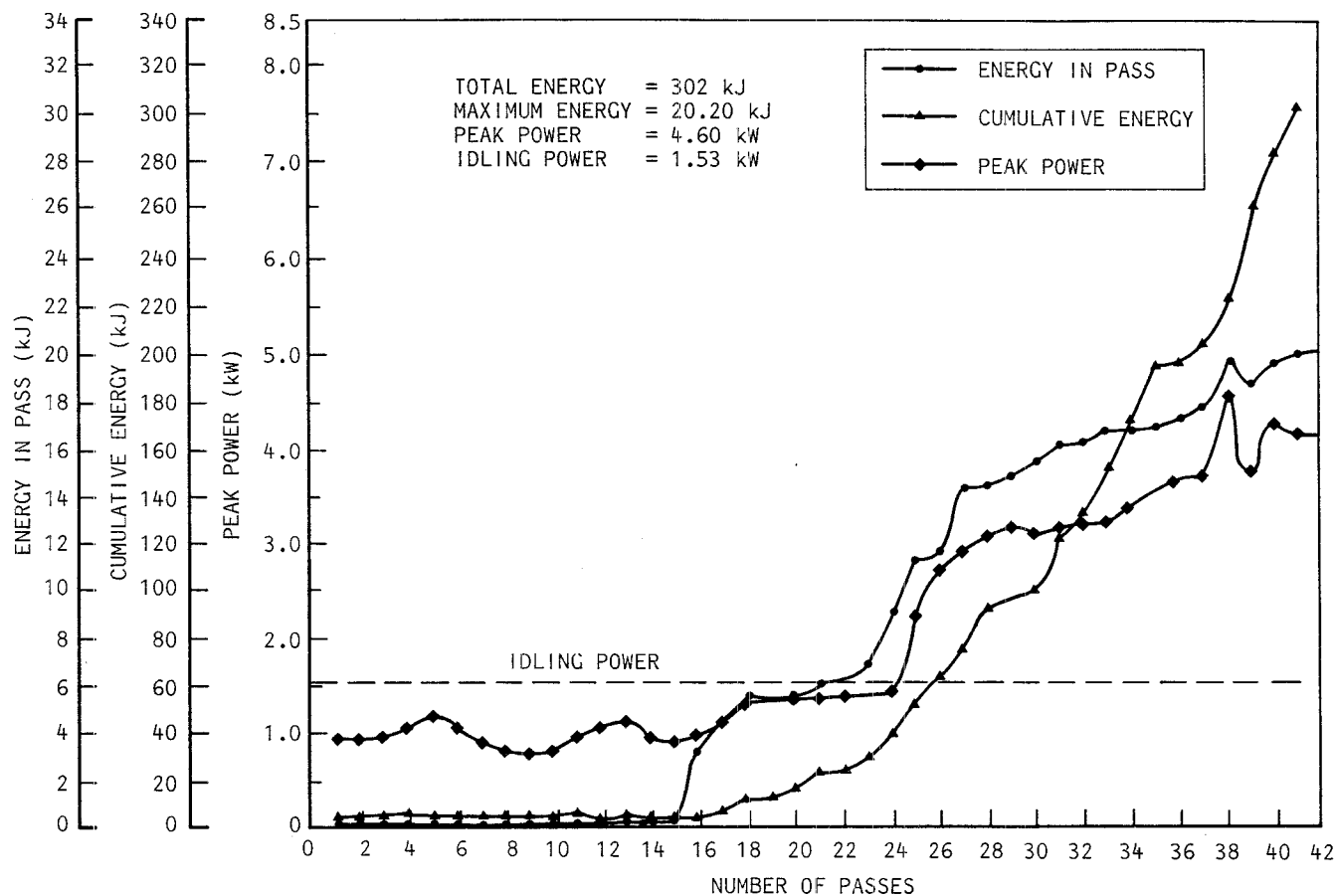
(a)

Figure 19. Roll mill power measurements



(b)

Figure 19(Contd.).



(c)

Figure 19(Contd.).

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## APPENDIX I

### THE NATURE OF TORQUE, POWER AND WORK

Work is done when energy is converted from one form to another. Therefore, when a body is moved through a distance by a force acting on it, work is done. Thus:

$$W = Fl$$

where  $W$  = work (N-m)  
 $F$  = force (N)  
 $l$  = distance (m)

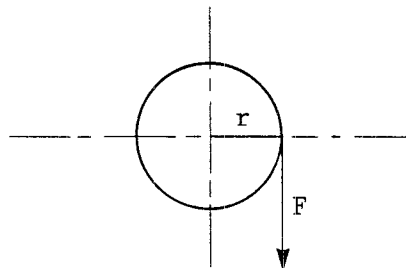
power is equal to the rate of doing work. Thus:

$$P = \frac{dW}{dt}$$

where  $P$  = power (W)  
 $dW$  = work increment (N-m)  
 $dt$  = time increment (min)

$$W = \int_0^t P dt \text{ (N-m)}$$

Torque is the effect of a force producing or tending to produce rotation of a body about a point. Therefore, torque can be present whether actual rotation occurs or where there is a tendency for rotation to occur and the torque is produced by a force acting at a distance perpendicular to an axis of rotation or pivot.



Thus:

$$T = Fr$$

where  $T$  = torque (N-m)  
 $F$  = force (N)  
 $r$  = radius (m)

The restraining forces or the turning moment is still  $T = Fr$  with the force  $F$  acting over a distance when  $Fr < T$ , and therefore work is being done. Instead of considering the distance moved, in a rotational situation, the speed of rotation can be considered as:

$$\omega = 2\pi n$$

where  $\omega$  = angular velocity (rad/s)  
 $n$  = rotational speed (rev/s)

Power is found from:

$$P = \omega T = 2\pi n T$$

where  $P$  = power (W)  
 $\omega$  = angular velocity (rad/s)  
 $T$  = torque (N-m)  
 $n$  = rotational speed (rev/s)

Collection equations:

$$W = \int_0^t P dt = \int_0^t \omega T dt = \int_0^t 2\pi n F r dt$$

Having formulated these equations, it can be seen that in order to measure the work done in a rotational situation, it is necessary to monitor time,  $t$  and measure power,  $P$ . If power is not measured directly, it can be found by measuring the angular velocity,  $\omega$ , force,  $F$  and radius,  $r$ .

## APPENDIX II

### ROLL MILL POWER MONITOR

#### II.1 Circuit and hardware

The electrical power input to the roll mill motor is continuously monitored by the University Graham AWT-33U Watt Transducer. This unit is connected as a 3 phase, 3 wire, unbalanced load wattmeter, sensing all three phase voltages (via fuses), and 2 line currents (via a 15:5 current transformer). The electrical terminations, fuses and current transformers (60:54) are located in the motor starting box.

The power transducer calculates the total real power input to the motor, allowing for power factors and unequal phase voltages, and outputs 0 to 10 mA dc current, corresponding to 0 to 10.8 kW full scale power (the transducer assumes the 15:5 current transformer ratio).

The 0 to 10 mA dc output from the power transducer is applied through a 1 K $\Omega$ , 1% metal film resistor, on the microcomputer board, producing a 0 to 10 Vdc voltage. This input is sampled as a negative voltage (by grounding the positive end), in the Track and Hold IC, U2.

The sampled output of U2 is converted to a 12 bit digital form by the CMOS A/D converter U4. U1 is a 10.24 V precision reference for the A/D converter, and serves as a stable supply for the analogue circuitry. The 12 bit CMOS output is converted to TTL levels by U5, 6 and appears at ports A and C(lower) of the PPI, U13.

Analogue sampling/conversion timing and digital timing impulse is generated by a 4 MHz quartz crystal oscillator, U7a,b,c. This drives the Z80A CPU, U14, and the programmable counter/timer chip U8, via the flip-flop U16a. From this 2 MHz input, the CTC is programmed to generate 200 kHz, which is divided by F/F U16b, to give a 100 kHz conversion clock for the A/D chip (via TTL/CMOS level shifter U3b).

Further division of the CTC produces the 5 kHz sampling rate which triggers the monostable U9a every 200  $\mu$ s. This monostable produces a 160  $\mu$ s pulse (set via a 50 k potentiometer) which causes the Track/Hold to 'hold' for the 130  $\mu$ s required to convert the sample. The leading (falling) edge of this pulse triggers U9b to output a 12.4  $\mu$ s 'start conversion' pulse to the converter via the TTL/CMOS level shifter U3a. Reference should be made to National Semiconductor's "Data Conversion/Acquisition" data book for more information on converter timing requirements.

The trailing (rising) edge of the 160  $\mu$ s 'hold' pulse, from U9a, triggers counter 1 in the CTC to generate a vectored interrupt in the CPU, causing the digital value to be read by the program (via the PPI, U13).

The PPI also handles the following I/O:

- output port bits B0,1 drive the RUN and IDLE SET lamps respectively
- input port bits C6,7 monitor the SET IDLE and RUN START switches respectively.
- C4,5 monitor the printer interfacing signals.

To minimise software polling of the switch inputs, this is done automatically, every 10 min, by an interrupt routine. The vectored



interrupt is generated by counter 3 of the CTC, after counting 50 of the 5 kHz sample pulses which are input to pin 20, from pin 9, of U8.

System memory comprises three sections:

- 4K byte EPROM(U12), program and fixed data
- 8K byte RAM(U10), for variable data
- 2K byte EPROM (U11), for non-volatile storage of idling levels, and run number

The memory is mapped onto the 64K addressing range as follows:

- 4K EPROM 0000H to 0FFFH
- 8K RAM C000H to DFFFH
- 2K EPROM A000H to A7FFH

This allocation requires only minimal address decoding.

I/O address decoding and peripheral selection is performed by the 3-to-8 decoder U15.

System resetting during power up is achieved by a long term constant RC network and U7f,d.

## II.2 Software and method

The operating program for the Z80A based microcomputer, was written in Zilog assembly language and assembled using a Philips PMDS2 development system. The program is contained in a 4K Byte 2732A EPROM.

The program operates as follows:

Immediately following the power-up reset, the system peripherals are initialised, ie PPI, CTC, lamps and printer (feeding 2 blank lines).

The program loops waiting for either RUN START or a SET IDLE command via the front panel switches. In the event of SET IDLE being pressed, the program enables illumination of the IDLE TEST lamp, ignores all other commands and executes the idle test routine.

The idle test routine acquires 32 768 samples of the idling power level (6.4 s work), which are then summed and averaged to give a value of average idle level (IDLEVL). Two higher levels are computed from this idle level, a 112.5% 'start level' (STALEV), which is basically a noise threshold, and a 125% 'valid level' (VALLEV), which serves as a threshold level for detecting valid passes.

The three levels are then stored in the non-volatile EPROM, to be recalled and used until updated by another SET IDLE command. On completion of the idle test routine, the program switches off the IDLE TEST lamp and resumes waiting for another command.

In the event of the RUN START command via the front panel switch, the program retrieves the latest idle and threshold levels, and the last RUN number (RUNNUM), from the EPROM. The RUN number is immediately incremented by 1 and restored in the non-volatile memory. A run header is printed, containing the current RUN number as a unique identifier, all computational

variables are reset, the run lamp is lit, and the program begins checking continuously for either a SET IDLE command (as before), or the start of a pass.

The method for detecting and processing a pass is as follows, referring to the diagram in figure 7.

Successive samples are checked against the START level (112.5% of idle), and discarded if lower. Once the samples exceed this limit, integration (summation) begins, ie the idle level is subtracted from the sample to give the nett energy applied to the work, and this is added to the sum.

In addition, the samples are compared with the VALID level (125% of idle). Once the samples have exceeded this threshold for the validation period of 100 ms, the detected 'power surge' is considered to be a valid pass - otherwise it remains only tentative.

The summation continues while each sample exceeds the START level. Summation ceases immediately the level is not met, and if not re-attained within the dropout period of 10 ms, the pass is considered finished. Should this occur before validation, the summation is discarded as a false alarm.

Immediately a valid pass has ended, the summation is divided by the sample rate (5000/s), to give the total nett energy applied to the work during that pass. This energy is printed out with the pass number, a running total of the pass energies so far, and the nett peak power (peak minus idling power) detected during the pass.

The program continues to detect and process passes in this manner until a RUN STOP command is detected. When this occurs, the run lamp is switched off and a run trailer is printed, being a summary of the detected passes.

The run summary consists of a total number of passes detected, total energy from all passes, the pass with maximum energy (and its value) and the pass with maximum peak power (and its value). Refer to page 41 for a sample of printout.

Program execution then reverts to its initial state, waiting for SET IDLE OR RUN START command, or to be powered down.

### II.3 Specifications

Power transducer type:	3 phase, 3 wire unbalanced load type
Maximum input power measurable:	10.8 kW
Power factor range:	0 to 1
Basic accuracy of power: transducer	maximum 0.5%, typically 0.2%
Input isolation:	voltage sensing - fuses current sensing - current transformers
Current transformer basic: turns ratio	60:5 A
Printer:	40 column, alphanumeric, ink ribbon dot matrix

Options:

can be modified to accept RS-232  
serial interface

Temperature (operating):

tested at 50° C for 2 hours

Power requirements:

210 - 250 Vac, 50 Hz, 15 W nominal.

SAMPLE PRINTOUT

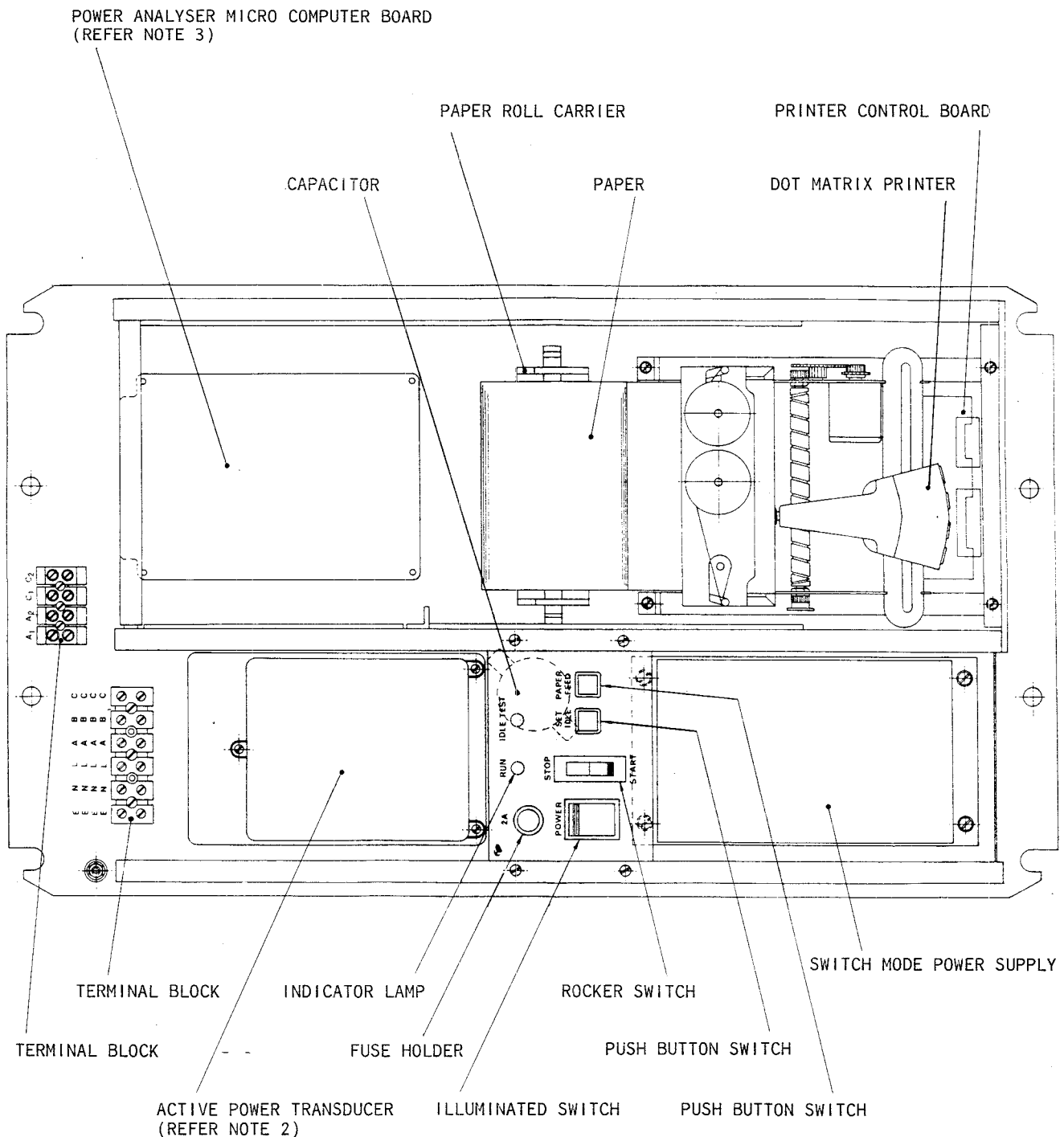
motor idling power,  
measured by idle test  
routine

\*\* Average idling power is 1.57 kW \*\*

RUN 00003

unique run number  
for reference

	Pass	Energy in Pass	Cumulative Energy	Peak Power	
	01 -	3.93 kJ	3.9 kJ	1.41 kW	
	02 -	4.57 kJ	8.5 kJ	1.49 kW	
	03 -	5.95 kJ	14.4 kJ	1.68 kW	
pass number	04 -	7.25 kJ	21.7 kJ	1.96 kW	peak power in
	05 -	8.02 kJ	29.7 kJ	1.99 kW	pass 5
	06 -	8.12 kJ	37.8 kJ	2.09 kW	
energy in pass 5	07 -	8.96 kJ	46.8 kJ	2.30 kW	total energy in
	08 -	8.20 kJ	55.0 kJ	2.34 kW	passes 1 to 5
	09 -	8.62 kJ	63.6 kJ	2.46 kW	
	10 -	8.56 kJ	72.2 kJ	2.35 kW	
	11 -	8.60 kJ	80.8 kJ	2.54 kW	
	12 -	8.71 kJ	89.5 kJ	2.44 kW	
	13 -	9.22 kJ	98.6 kJ	2.63 kW	
	14 -	9.26 kJ	107.9 kJ	2.37 kW	
	15 -	9.34 kJ	117.2 kJ	3.01 kW	
	16 -	9.75 kJ	127.0 kJ	2.71 kW	
	17 -	9.88 kJ	136.9 kJ	2.98 kW	
	18 -	10.02 kJ	146.9 kJ	2.70 kW	pass with maximum energy
pass with maximum peak power	Run finished - 18 Passes				
	Total Energy : 146.9 kJ				total energy
	Maximum energy : 10.02 kJ, in Pass 18				in all passes
	Peak Power : 3.01 kW in Pass 15				



## NOTES:

1. THIS UNIT IS MOUNTED INSIDE A WALL MOUNTING CABINET, SIZE = 380 x 600 x 210 mm "RITTAL" AE1038.
2. 2 CURRENT TRANSFORMERS. 60:5A ARE MOUNTED IN MOTOR STARTER BOX.
3. REFER TO DRG. NO HDHSD 87-3 OR CIRCUIT OF BOARD.
4. INTERCONNECTING DIAGRAM FOR SYSTEM SHOWN ON DRG. NO HDHSD 87-2.

Figure II.1 Layout of rolling mill power analyser

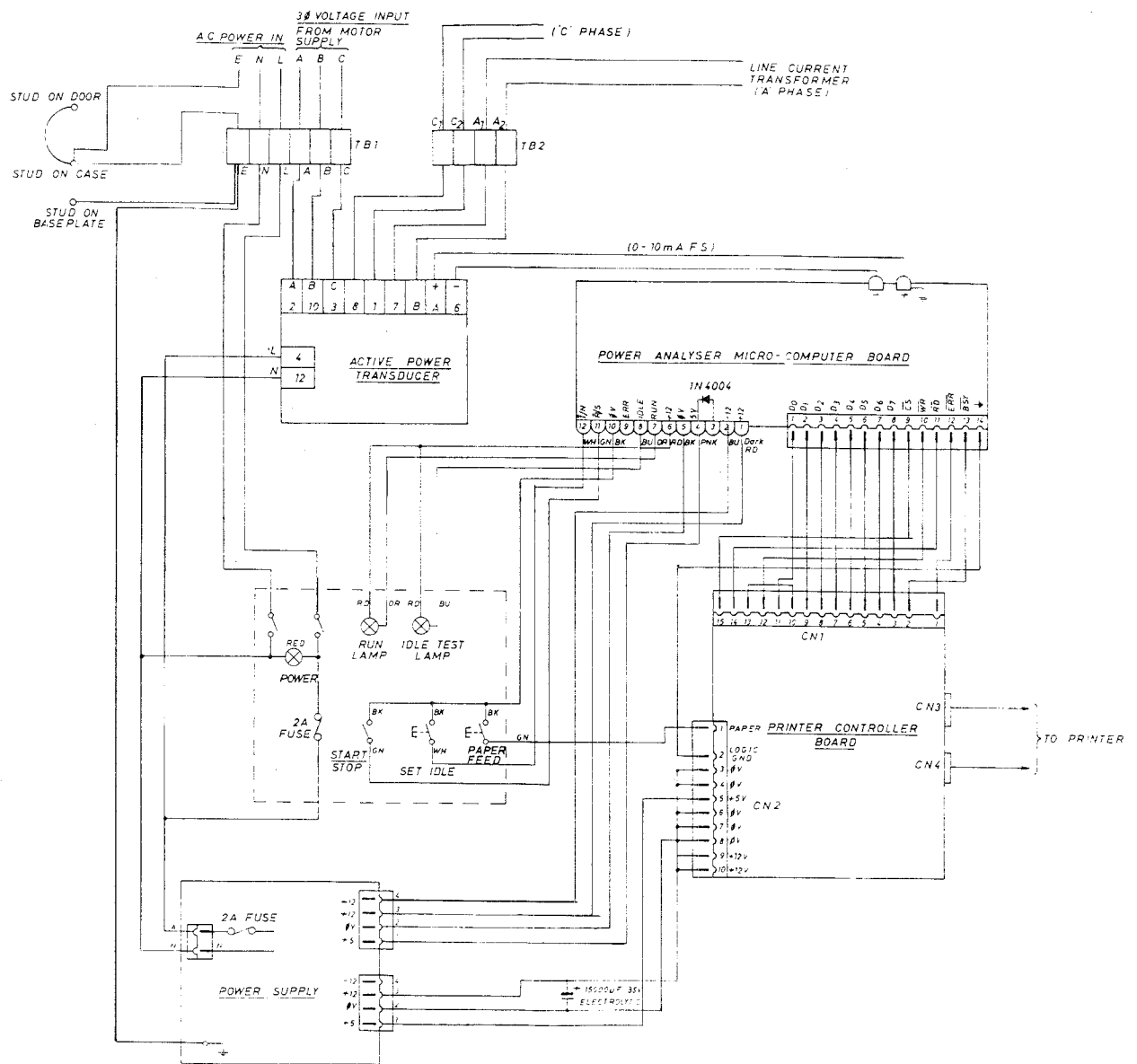


Figure II.2 Inter connecting diagram for rolling mill power analyser unit

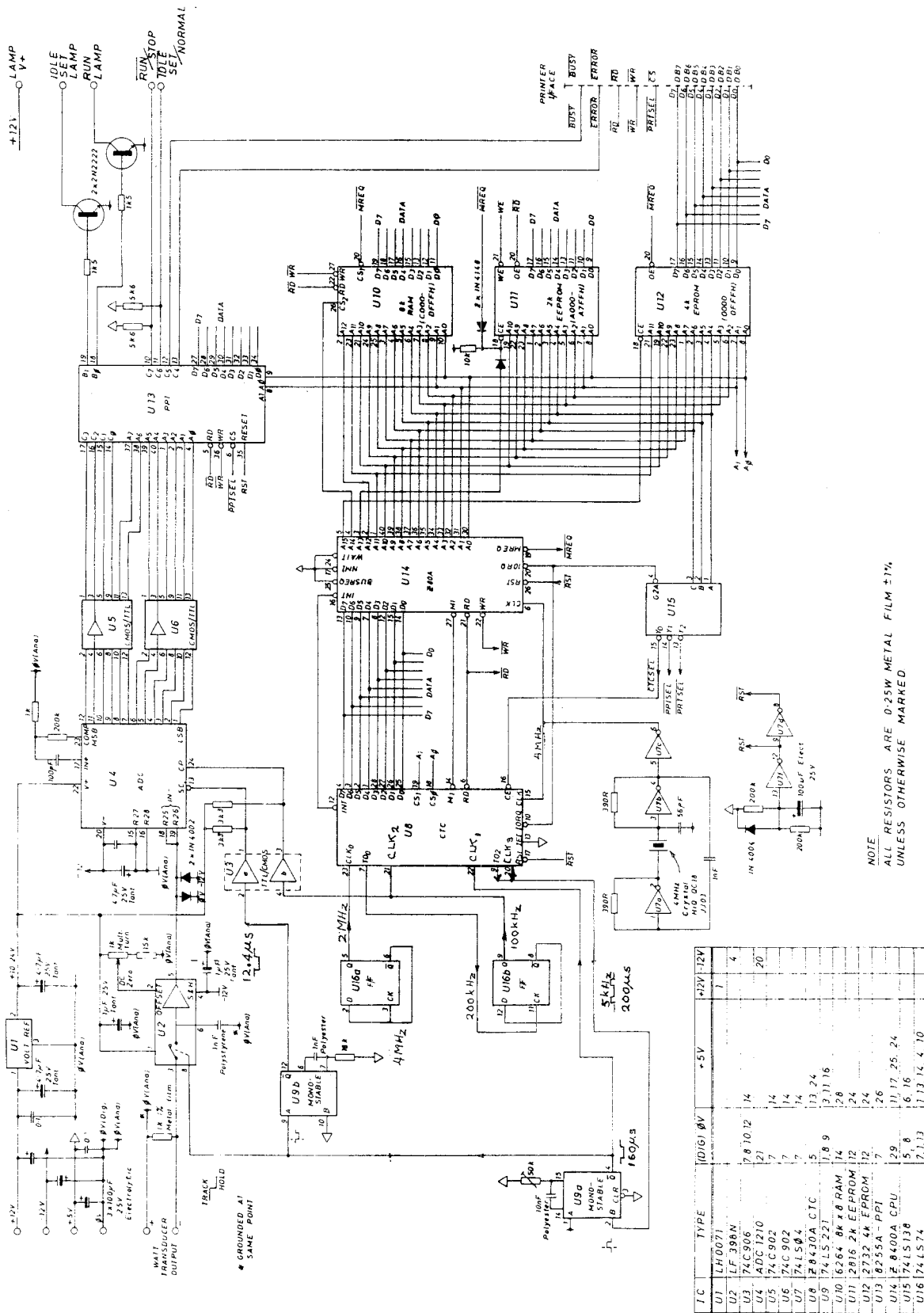


Figure II.3 Power analyser micro-computer board schematic

## APPENDIX III

## HIOKI TESTER SPECIFICATIONS

The Hioki clamp-on power hi tester is an instrument designed for taking readings on uninterrupted live lines. Power is measured directly by measuring the input power to the mixer motor.

A block diagram of the clamp-on hi tester is overleaf. The clamp incorporates high permeability magnetic material and a Hall element. The clamps are used to measure current and in conjunction with the measurement of the line voltages, the effective power can be measured. From this power, the no load power is subtracted from the loaded power readings to allow for motor losses. Work is then found from:

$$W = \int_0^t \Delta P dt = \Sigma \Delta P t$$

where W = work (N-m)  
ΔP = power measured - power no load (W)  
dt = time increment (min)  
t = time (min)



## SPECIFICATIONS

Model	3133	3134
Testing capability	AC voltage and current, single-phase and 3 phase effective power and 3-phase reactive power	
Ranges	AC V, AC A, Watts, var - 2 ranges for each	
AC V(V)	200, 500(2,000)	200, 500(2000)
AC A(A)	20, 200	200, 1,000(2000)
Watts(kW)	20, 200	200, 1,000(2000)
Var(kvar)	20, 200	200, 1,000(2000)
Accuracy (at 23° ± 5°C)	±1% rdg ±0.5% fs (At effective power : power factor = 1 Reactive power : reactive factor = 1)	
Output terminals	Two channels, 2V to maximum indicated reading for each range (output resistance approx. 50 Ω)	
Frequency characteristics	Not over ±0.1% for 40 ~ 500 Hz frequency (At effective power : power factor = 1 Reactive power : reactive factor = 1)	
Temperature characteristics	Not over ±0.1% for temperatures from 0 to 40°C	
Display	LED 3½ digits(1999)	
Effect of power factor and reactive factor	Not over ±1.5% at power factor = 0.5 (Reactive factor in the case of var)	
Influence of position of conductor	Variation not more than 1% no matter what the position of the line is in the core	
Temperature range for use	-10°C to ±50°C	
Max circuit voltage able to be tested	500 Vrms	
Max diameter of line able to be tested	Approx DIA 300 mm	Approx DIA 46 mm
Effect of external magnetic field	In the case of watts, fluctuation not over ±0.5% for a 400 A m external magnetic field	
External dimensions and weight		
Main body of tester	150H X 215W X 300D mm; Approx 5.5 kg	
Clamp sensor	175H X 85W X 40D mm, 600 g	190H X 90 W X 40D mm, 650 g
Lead length	3 m	3 m
Accessories		
Clamp-on sensor	9001(Two)	9002(Two)
Clamp carrying case	One	

Voltage leads	One
Operator's manual	One
Spare fuses	Two 0.5 A and two Midget 0.3 A fuses

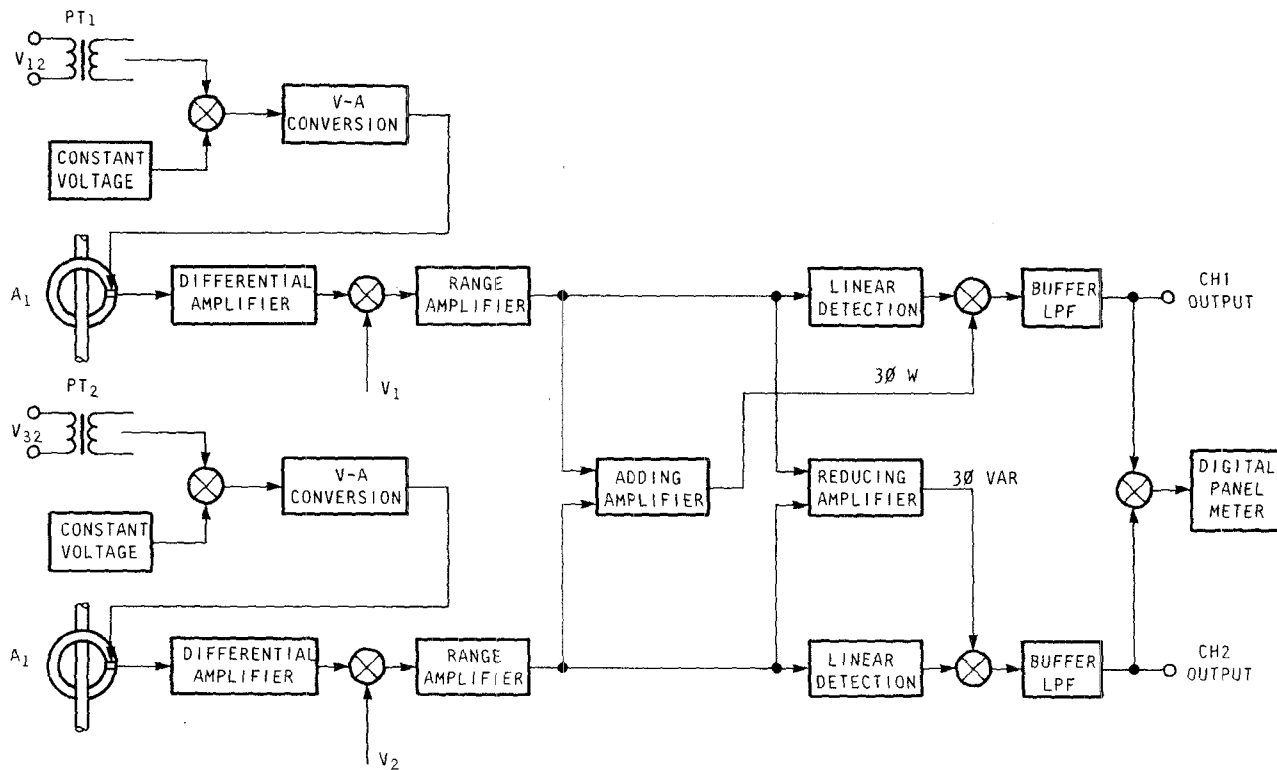


Figure III.1(a) Block diagram of Clamp on Hi Tester

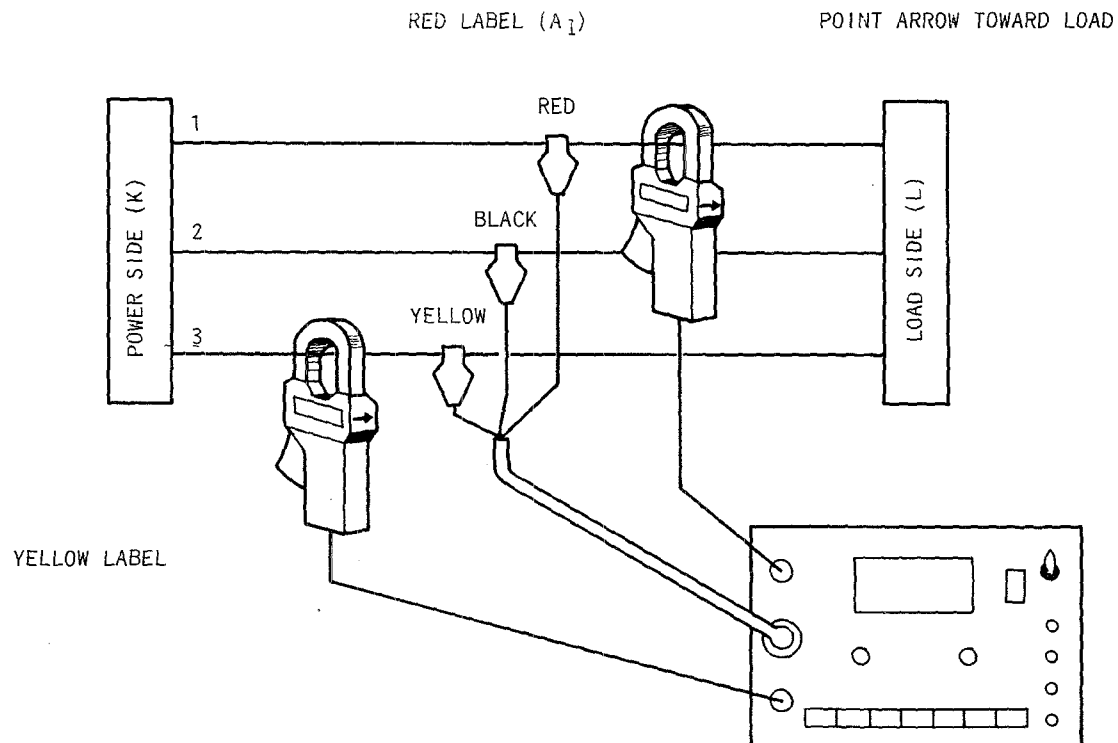


Figure III.1(b) Wiring diagram for 3-phase effective and reactive power testing (3-phase 3-wire system)

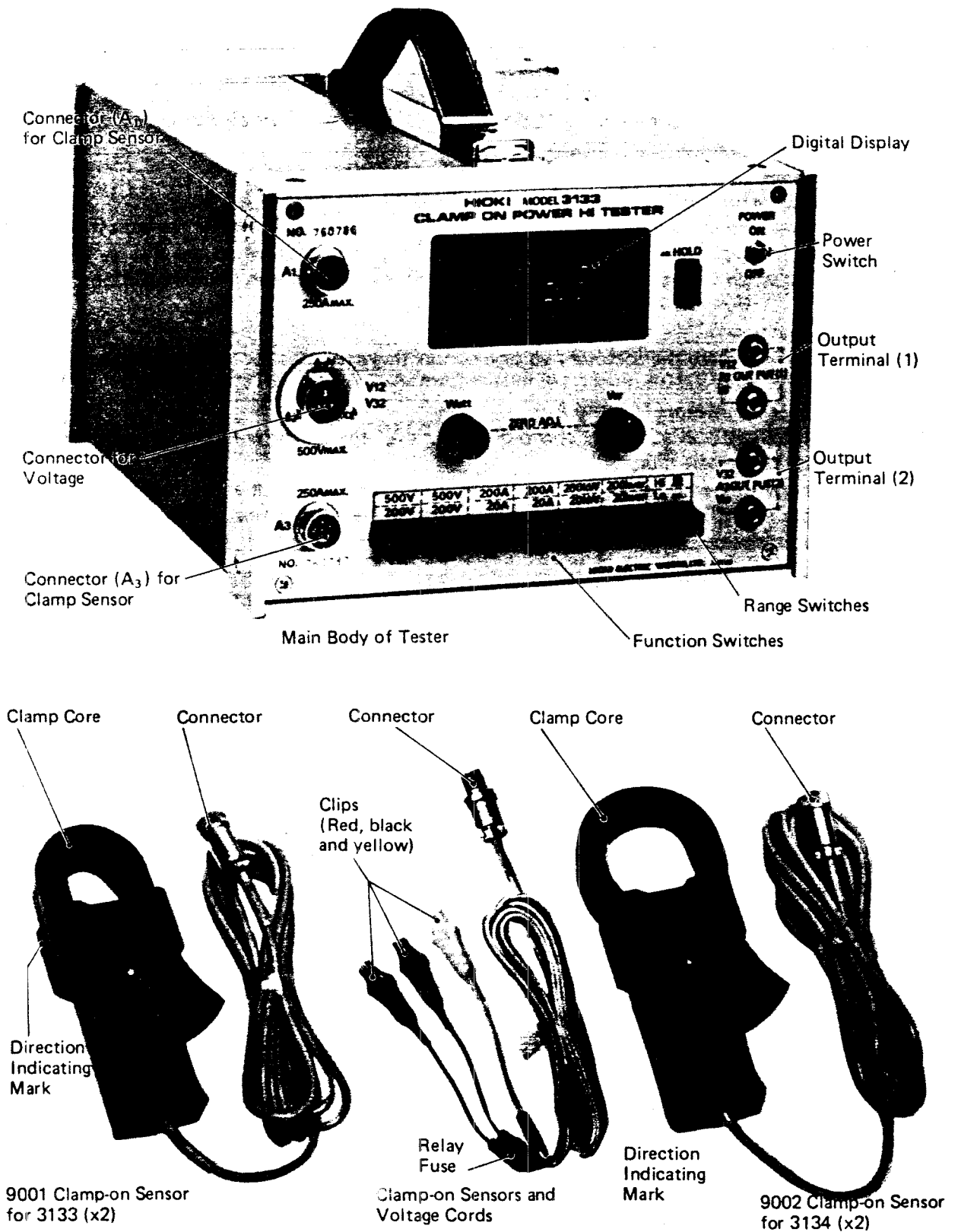


Figure III.2 Hioki (Model 3133) clamp on power hi tester parts

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(if this is security classified, the announcement of this report will be similarly classified)

This report deals with the principles, application and performance of load and work sensing techniques used on propellant mixers and rolling mills. The current and recommended alternative methods used in load sensing during manufacture of propellants are outlined.